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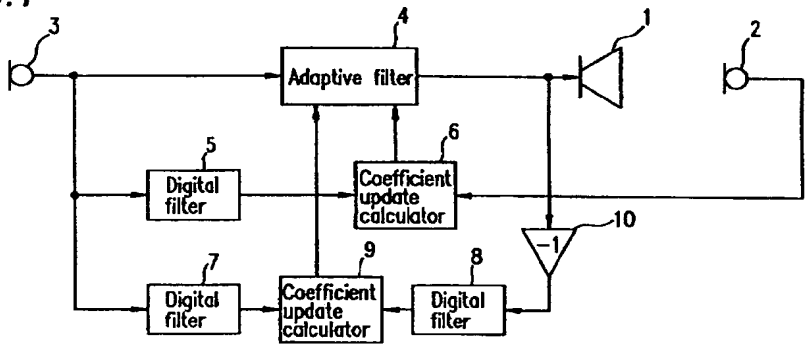
(54) Noise control system

(57) A noise control system includes: a control sound generator (1) for generating a control sound; an error detector (2) for detecting an error signal between the control sound and noise; a noise detector (3) for detecting a noise source signal; an adaptive filter (4) for outputting a control signal; and a coefficient updator for updating a coefficient of the adaptive filter (4). The coefficient updator includes at least a first digital filter (5), a first coefficient update calculator (6), a second digital filter (7), a phase inverter (10), a third digital filter (8), and a second coefficient update calculator (9). Alternatively, the coefficient updator includes at least a first digital filter, a second digital filter, a third digital filter, a coefficient update calculator, a phase inverter, a first adder, and a second adder. In either case, the coefficient updator has a function of suppressing an increase in a coefficient gain of the adaptive filter in a predetermined frequency band.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION:

[0001] The present invention relates to a noise control system based on active noise control, for use in a noisy environment.

2. DESCRIPTION OF THE RELATED ART:

[0002] In recent years, an active noise control system has been proposed which eliminates environmental noise, using a control sound from a loud speaker, etc. This type of a noise control system in the conventional art employs an adaptive filter for calculating a noise control signal, and may further employ an auxiliary adaptive filter for preventing an increase in the gain of the adaptive filter, as disclosed in, for example, Japanese Laid-Open Publication No. 5-67948.

[0003] Figure **22** is a block diagram illustrating a structure of such a conventional noise control system. Referring to Figure **22**, the noise control system includes a control speaker **1**, an error detection microphone **2** which functions as an error detector, a noise detection microphone **3** which functions as a noise detector, adaptive filters **4** and **15**, a digital filter **5** which approximates the propagation characteristic between the control speaker **1** and the error detection microphone **2**, coefficient update calculators **6** and **9**, and a digital filter **7** having a frequency band limiting characteristic.

[0004] With the structure illustrated in Figure **22**, noise generated from a noise source is detected by the noise detector **3**, and a noise source signal is generated based on the detection result. The generated noise source signal is processed by the adaptive filter **4**, so as to output a control signal. A control sound is generated from the control speaker **1** based on the control signal so that the control sound interferes with the noise from the noise source, thereby reducing the noise.

[0005] Moreover, the state of interference between the control sound output from the control speaker **1** and the noise is measured by the error detector (microphone) **2**. The output of the error detector (microphone) **2** should ideally be zero as a result of the noise control. Therefore, the coefficient update calculator **6** performs a calculation such that the output signal of the error detector (microphone) **2** is reduced, and controls the coefficient of the adaptive filter **4** based on the calculation result.

[0006] On the other hand, the coefficient update calculator **9** performs a calculation such that the output of the adaptive filter **15** is reduced, and controls the coefficient of the adaptive filter **15** based on the calculation result. A band limiting signal produced by the digital filter **7** is input to the adaptive filter **15**, and the coefficient of the adaptive filter **15** converges into a value which suppresses signals in the band. The coefficients of the adaptive filters **4** and **15** can be shared by each other so as to combine the effects of the two coefficient update calculators **6** and **9** together, and the update operation of the coefficient of the adaptive filter **4** is suppressed in a band which is set in the digital filter **7**.

[0007] Figure **23** is a block diagram illustrating a structure of another conventional noise control system as disclosed in Japanese Laid-Open Publication No. 7-271383. Referring to Figure **23**, the noise control system includes a control speaker **1**, an error detection microphone **2** which functions as an error detector, a noise detection microphone **3** which functions as a noise detector, an adaptive filter **4**, a digital filter **5** which approximates the propagation characteristic between the control speaker **1** and the error detection microphone **2**, coefficient update calculators **6** and **9**, digital filters **7** and **8** each having a frequency band limiting characteristic, and a switch section **32**.

[0008] With the structure illustrated in Figure **23**, noise generated from a noise source is detected by the noise detector **3**, and a noise source signal is generated based on the detection result. The generated noise source signal is processed by the adaptive filter **4**, so as to output a control signal. A control mound is generated from the control speaker **1** based on the control signal so that the control sound interferes with the noise from the noise source, thereby reducing the noise.

[0009] Moreover, the state, of interference between the control sound output from the control speaker **1** and the noise is measured by the error detector (microphone) **2**. The output of the error detector (microphone) **2** should ideally be zero as a result of the noise control. Therefore, the coefficient update calculator **6** performs a calculation such that the output signal of the error detector (microphone) **2** is reduced. A band limiting signal produced by the digital filter **7** and another band limiting signal produced by the digital filter **8** are input to the coefficient update calculator **9**, and the coefficient update calculator **9** performs a coefficient update calculation such that the adaptive filter **4** suppresses the output of the signal in the band. The switch section **32** switches between the outputs of the coefficient update calculators **6** and **9**, so as to control the update operation of the band limitation by the digital filters **7** and **8**.

[0010] However, the conventional noise control system as illustrated in Figure **22** requires the auxiliary adaptive filter **15** for controlling the update operation of the coefficient of the adaptive filter **4**, thereby increasing the amount of calculation to be performed.

[0011] The other conventional noise control system as illustrated in Figure **23** requires two coefficient update calculators **6** and **9**, thereby increasing the amount of calculation to be performed. Moreover, since the switching between the outputs of the coefficient update calculators **6** and **9** is done by the switch section **32**, coefficient update operations of the adaptive filter by the coefficient update calculators **6** and **9** cannot be arbitrarily weighed.

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SUMMARY OF THE INVENTION

[0012] A noise control system of the present invention includes: a control sound generator for generating a control sound; an error detector for detecting an error signal between the control sound and noise; a noise detector for detecting a noise source signal; an adaptive filter for outputting a control signal; and a coefficient updator for updating a coefficient of the adaptive filter, the coefficient updator comprising at least a first digital filter, a first coefficient update calculator, a second digital filter, a phase inverter, a third digital filter, and a second coefficient update calculator. The coefficient updator has a function of suppressing an increase in a coefficient gain of the adaptive filter in a predetermined frequency band.

[0013] In one embodiment, the coefficient updator is such that: the first digital filter receives, as an input thereto, an output of the noise detector; the first coefficient update calculator receives, as inputs thereto, an output of the first digital filter and an output of the error detector; the phase inverter inverts the output of the noise detector; the second digital filter receives, as an input thereto, an output of the phase inverter; the third digital filter receives, as an input thereto, the output of the error detector; the second coefficient update calculator receives, as inputs thereto, outputs of the second and third digital filters; the first digital filter approximates a propagation characteristic between the control sound generator and the error detector; the second and third digital filters have a common passband frequency characteristic; the first coefficient update calculator performs a calculation such that the output of the error detector is reduced, and updates the coefficient of the adaptive filter based on the calculation result; and the second coefficient update calculator performs a calculation such that the output of the third digital filter is reduced, and updates the coefficient of the adaptive filter based on the output of the coefficient update calculator.

[0014] In another embodiment, the coefficient updator is such that: the first digital filter receives, as an input thereto, an output of the noise detector; the first coefficient update calculator receives, as inputs thereto, an output of the first digital filter and an output of the error detector; the second digital filter receives, as an input thereto, an output of the noise detector; the third digital filter receives, as an input thereto, the output of the error detector; the second coefficient update calculator receives, as inputs thereto, outputs of the second and third digital filters; the phase inverter inverts an output of the second coefficient update calculator; the first digital filter approximates a propagation characteristic between the control sound generator and the error detector; the second and third digital filters have a common passband frequency characteristic; the first coefficient update calculator performs a calculation such that the output of the error detector is reduced, and updates the coefficient of the adaptive filter based on the calculation result; and the second coefficient update calculator performs a calculation such that the output of the third digital filter is reduced, inverts and outputs the calculation result, and updates the coefficient of the adaptive filter based on the output of the second coefficient update calculator.

[0015] In still another embodiment, the coefficient updator further includes: a first selection controller for thinning out the outputs of the first coefficient update calculator; a second selection controller for thinning out the outputs of the second coefficient update calculator; and a selection control calculator for receiving an output signal of the third digital filter to control the first and second selection controllers; the first digital filter receives, as an input thereto, an output of the noise detector; the first coefficient update calculator receives, as inputs thereto, an output of the first digital filter and an output of the error detector; the phase inverter inverts an output of the adaptive filter; the third digital filter receives, as an input thereto, an output of the phase inverter; the second coefficient update calculator receives, as inputs thereto, outputs of the second and third digital filters; the first digital filter approximates a propagation characteristic between the control sound generator and the error detector; the second and third digital filters have a common passband frequency characteristic; the first coefficient update calculator performs a calculation such that the output of the error detector is reduced; the second coefficient update calculator performs a calculation such that the output of the third digital filter is reduced; and when a level of the output signal of the third digital filter exceeds a predetermined value, the selection control calculator updates the coefficient of the adaptive filter by controlling the first and second selection controllers so that the first selection controller performs the thinning-out operation at a thinning-out frequency lower than that of the second selection controller.

[0016] In still another embodiment, the coefficient updator further includes a a first selection controller for switching between selecting an output of the first coefficient update calculator and selecting nothing; a second selection controller for switching between selecting an output of the second coefficient update calculator and selecting nothing; and a selection control calculator for receiving an output signal of the third digital filter to control the first and second selection controllers; the first digital filter receives, as an input thereto, an output of the noise detector; the first coefficient update calculator receives, as inputs thereto, an output of the first digital filter and an output of the error detector; the phase inverter inverts an output of the adaptive filter; the third digital filter receives, as an input thereto, an output of the phase inverter; the second coefficient update calculator receives, as inputs thereto, outputs of the second and third digital filters; the first digital filter approximates a propagation characteristic between the control sound generator and the error detector; the second and third digital filters have a common passband frequency char-

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acteristic; the first coefficient update calculator performs a calculation such that the output of the error detector is reduced; the second coefficient update calculator performs a calculation such that the output of the third digital filter is reduced; and when a level of the output signal of the third digital filter exceeds a predetermined value, the selection control calculator updates the coefficient of the adaptive filter by controlling the first and second selection controllers so that the first selection controller is switched to select nothing at a switching operation frequency lower than that at which the second selection controller is switched to select nothing.

[0017] In still another embodiment, the coefficient updator further includes: a signal level converter for receiving an output signal of the third digital filter to convert a level of the signal; and a multiplier for multiplying an output of the signal level converter by an output of the second coefficient update calculator so as to update the coefficient of the adaptive filter; the first digital filter receives, as an input thereto, an output of the noise detector; the first coefficient update calculator receives, as inputs thereto, an output of the first digital filter and an output of the error detector; the second digital filter receives, as an input thereto, the output of the noise detector; the phase inverter inverts an output of the adaptive filter; the third digital filter receives, as an input thereto, an output of the phase inverter; the second coefficient update calculator receives, as inputs thereto, outputs of the second and third digital filters; the first digital filter approximates a propagation characteristic between the control sound generator and the error detector; the second and third digital filters have a common passband frequency characteristic; the first coefficient update calculator performs a calculation such that the output of the error detector is reduced; the second coefficient update calculator performs a calculation such that the output of the third digital filter is reduced; and the signal level converter has an input-output characteristic which is approximated to a characteristic obtained by normalizing an input-distortion characteristic of the control sound generator.

[0018] In each of the above-described configurations, the predetermined frequency band may exist in a low frequency region.

[0019] For example, the predetermined frequency band may be a frequency region where the frequency is less than or equal to a lower limit reproducible frequency of the control sound generator.

[0020] Another noise control system of the present invention includes: a control sound generator for generating a control sound; an error detector for detecting an error signal between the control sound and noise; a noise detector for detecting a noise source signal; an adaptive filter for outputting a control signal; and a coefficient updator for updating a coefficient of the adaptive filter, the coefficient updator comprising at least a first digital filter, a second digital filter, a third digital filter, a coefficient update calculator, a phase inverter, a first adder, and a second adder. The coefficient updator has a function of suppressing an increase in a coefficient gain of the adaptive filter in a predetermined frequency band.

[0021] In one embodiment, the coefficient updator is such that: the first digital filter receives, as an input thereto, an output of the noise detector; the second digital filter receives, as an input thereto, the output of the noise detector; the first adder receives, as inputs thereto, an output of the first digital filter and an output of the second digital filter; the second adder receives, as inputs thereto, an output of the error detector and an output of the third digital filter; the coefficient update calculator receives, as inputs thereto, an output of the first adder and an output of the second adder; the phase inverter inverts an output of the adaptive filter; the third digital filter receives, as an input thereto, the output of the phase inverter; the first digital filter approximates a propagation characteristic between the control sound generator and the error detector; the second and third digital filters have a common passband frequency characteristic; and the coefficient update calculator performs a calculation such that the output of the second adder is reduced, and updates the coefficient of the adaptive filter based on the calculation result.

[0022] In another embodiment, the coefficient updator is such that: the first digital filter receives, as an input thereto, an output of the noise detector; the phase inverter inverts the output of the noise detector: the second digital filter receives, as an input thereto, the output of the phase inverter; the first adder receives, as inputs thereto, an output of the first digital filter and an output of the second digital filter; the second adder receives, as inputs thereto, an output of the error detector and an output of the third digital filter; the coefficient update calculator receives, as inputs thereto, an output of the first adder and an output of the second adder; the third digital filter receives, as an input thereto, an output of the adaptive filter; the first digital filter approximates a propagation characteristic between the control sound generator and the error detector; the second and third digital filters have a common passband frequency characteristic; and the coefficient update calculator performs a calculation such that the output of the second adder is reduced, and updates the coefficient of the adaptive filter based on the calculation result.

[0023] In still another embodiment, the coefficient updator further includes: a first coefficient controller for multiplying an output of the second digital filter by a first coefficient factor; and a second coefficient controller for multiplying an output of the third digital filter by a second coefficient factor; the first digital filter receives, as an input thereto, an output of the noise detector; the second digital filter receives, as an input thereto, the output of the noise detector; the first adder receives, as inputs thereto, an output of the first digital filter and an output of the first coefficient controller; the second adder receives, as inputs thereto, an output of the error detec-

tor and an output of the second coefficient controller; the coefficient update calculator receives, as inputs thereto, an output of the first adder and an output of the second adder; the phase inverter inverts an output of the adaptive filter; the third digital filter receives, as an input thereto, the output of the phase inverter; each of the first coefficient factor and the second coefficient factor is set to be equal to or more than 1; the first digital filter approximates a propagation characteristic between the control sound generator and the error detector; the second and third digital filters have a common passband frequency characteristic; and the coefficient update calculator performs a calculation such that the output of the second adder is reduced, and updates the coefficient of the adaptive filter based on the calculation result.

[0024] For example, the first coefficient controller may be set so that in a passband of the second digital filter, the output of the first coefficient controller is larger than an output signal of the first digital filter. Alternatively, the second coefficient controller may be set so that in a passband of the third digital filter, the output of the second coefficient controller is larger than an output signal of the error detector.

[0025] In one embodiment, the coefficient updator further includes: a first coefficient controller for multiplying an output of the first digital filter by a first coefficient factor; and a second coefficient controller for multiplying an output of the error detector by a second coefficient factor; the first digital filter receives, as an input thereto, an output of the noise detector; the second digital filter receives, as an input thereto, the output of the noise detector; the first adder receives, as inputs thereto, an output of the first coefficient controller and an output of the second digital filter; the second adder receives, as inputs thereto, an output of the second coefficient controller and an output of the third digital filter; the coefficient update calculator receives, as inputs thereto, an output of the first adder and an output of the second adder; the phase inverter inverts an output of the adaptive filter; the third digital filter receives, as an input thereto, the output of the phase inverter; each of the first coefficient factor and the second coefficient factor is set to be less than or equal to 1; the first digital filter approximates a propagation characteristic between the control sound generator and the error detector; the second and third digital filters have a common passband frequency characteristic; and the coefficient update calculator performs a calculation such that the output of the second adder is reduced, and updates the coefficient of the adaptive filter based on the calculation result.

[0026] For example, the first coefficient controller may be set so that in a passband of the second digital filter, the output of the first coefficient controller is smaller than an output signal of the first digital filter. Alternatively, the second coefficient controller may be set so that in a passband of the third digital filter, the output of the second coefficient controller is smaller than an output signal of the error detector.

[0027] In each of the above-described configurations, the predetermined frequency band may exist in a low frequency region.

[0028] For example, the predetermined frequency band may be a frequency region where the frequency is less than or equal to a lower limit reproducible frequency of the control sound generator.

[0029] The predetermined frequency band may exist in a frequency region where there is a correlation between an output signal of the noise detector and an output signal of the error detector.

[0030] With the noise control system of the present invention having the features as described above, the noise detection signal and the adaptive filter output signal are processed by the band limiting digital filters, which have the same characteristic, so as to produce a coefficient update signal in the negative direction from both of the output signal, thereby controlling the adaptive filter used in a noise control calculation. In this way, the present invention prevents an undesired increase in the coefficient gain of the adaptive filter in the band of the above-described digital filter, while realizing a coefficient control of the adaptive filter used in a noise control calculation without having to use additional hardware such as an adaptive filter or an additional calculation process, thereby realizing a stable noise processing operation.

[0031] Moreover, the update frequency, at which the negative coefficient update for the adaptive filter is performed, is controlled in view of the non-linear characteristic of the noise propagation system or the control sound generator, whereby it is possible to realize a noise control with no band limitation when the noise signal is small.

[0032] Thus, the invention described herein makes possible the advantage of providing a noise control system capable of a stable noise processing operation by controlling the coefficient of an adaptive filter used in noise control calculations without having to provide additional hardware such as an adaptive filter or an additional calculation process.

[0033] This and other advantages of the present invention will become apparent to those skilled in the art upon reading and understanding the following detailed description with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034]

Figure **1** is a block diagram illustrating a structure of a noise control system according to Embodiment 1 of the present invention;

Figure **2** illustrates a sound pressure-frequency characteristic of a control speaker which may be included in the structure of the present invention;

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Figure **3** illustrates a gain-frequency characteristic of an adaptive filter which is obtained by using only the coefficient update calculator **6** which is included in the structure of the present invention;

Figure **4** illustrates a noise control characteristic while the control speaker is in a linear region;

Figure **5** illustrates an input-output characteristic of the control speaker which may be included in the structure of the present invention;

Figure **6** illustrates an input-sound pressure distortion characteristic of the control speaker which may be included in the structure of the present invention;

Figure **7** illustrates a noise control characteristic while the control speaker is in a non-linear region;

Figure **8** illustrates a gain-frequency characteristic of digital filters **7** and **8** which are included in the structure of the present invention;

Figure **9** illustrates a gain-frequency characteristic of the adaptive filter which is obtained by using the entire structure of the present invention;

Figure **10** illustrates a noise control characteristic obtained by the structure of the present invention;

Figure **11** is a block diagram illustrating a structure of a modified noise control system according to Embodiment **1** of the present invention;

Figure **12** is a block diagram illustrating a structure of another modified noise control system according to Embodiment **1** of the present invention;

Figure **13** is a block diagram illustrating a structure of a noise control system according to Embodiment **2** of the present invention;

Figure **14** is a block diagram illustrating a structure of a noise control system according to Embodiment **3** of the present invention;

Figure **15** illustrates an input-output characteristic of a signal level converter which is included in the structure illustrated in Figure **14**;

Figure **16** is a block diagram illustrating a structure of a noise control system according to Embodiment **4** of the present invention;

Figure **17** illustrates a gain-frequency characteristic of the digital filters **7** and **8** which are included in the structure illustrated in Figure **16**;

Figure **18** is a block diagram illustrating a structure of a modified noise control system according to Embodiment **4** of the present invention;

Figure **19** is a block diagram illustrating a structure of another modified noise control system according to Embodiment **4** of the present invention;

Figure **20** is a block diagram illustrating a structure of still another modified noise control system according to Embodiment **4** of the present invention;

Figure **21** is a block diagram illustrating a structure of a noise control system according to Embodiment **5** of the present invention;

Figure **22** is a block diagram illustrating a structure of a conventional noise control system; and

Figure **23** is a block diagram illustrating a structure of another conventional noise control system.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiment 1

[0035] A noise control system according to Embodiment 1 of the present invention will be described below with reference to the accompanying figures.

[0036] In the present embodiment, a low frequency band of the control signal is limited so that the adaptive filter does not generate an excessive control signal for noise having a frequency which is too low for the low band reproducibility of the control speaker.

[0037] Figure **1** is a block diagram illustrating a structure of the noise control system of this embodiment. Referring to Figure **1**, the noise control system includes a control speaker **1**, an error detection microphone **2** which functions as an error detector, a noise detection microphone **3** which functions as a noise detector, an adaptive filter **4**, a digital filter **5** which approximates the propagation characteristic between the control speaker **1** and the error detection microphone **2**, coefficient update calculators **6** and **9**, digital filters **7** and **8** each having a frequency band limiting characteristic (band limiting filters), and a phase inverter **10** for inverting the output of the adaptive filter **4**.

[0038] With the structure illustrated in Figure **1**, noise generated from a noise source is detected by a noise detector **3**, and a noise source signal is generated based on the detection result. The generated noise source signal is processed by the adaptive filter **4**, so as to output a control signal. A control sound is generated from the control speaker **1** based on the control signal so that the control sound interferes with the noise from the noise source, thereby reducing the noise.

[0039] Moreover, the state of interference between the control sound output from the control speaker **1** and the noise is measured by the error detector (microphone) **2**. The output of the error detector (microphone) **2** should ideally be zero as a result of the noise control. Therefore, the coefficient update calculator **6** performs a coefficient update calculation as shown in Expression (1) later based on a filtered X-LMS method (see Widrow and Stearns, "Adaptive Signal Processing", 1985), or the like, so as to adjust the characteristic of the adaptive filter **4**, such that the output signal of the error detector (microphone) **2** is reduced. This changes the control sound actually generated from the control speaker **1**, thereby further reducing the noise.

[0040] Typically, the frequency characteristic of the control speaker **1** is such that the sound pressure of an output thereof is reduced in a frequency region where the frequency is less than or equal to the lower limit reproducible frequency f_L, as shown in Figure **2**. For example, in the case where noise has a spectrum which includes such a low frequency region, if only the coefficient update calculator **6** is used for updating the coefficient of the adaptive filter **4**, the coefficient gain of the adaptive filter **4** is required to sufficiently reduce (or cancel) the noise in the low frequency region while compensating for the characteristic of the control speaker **1**, thereby converging into the characteristic as illustrated in Figure **3**, where the gain has an increase in the low frequency region (a region where the frequency is less than or equal to the lower limit reproducible frequency f_L of the control speaker **1**). In such a case, a large low frequency signal is input to the control speaker **1**.

[0041] In a region where the linearity of the control speaker is maintained, even if the noise spectrum at the error detector (microphone) **2** includes signals in the vicinity of a low frequency f1 as illustrated by a broken line (a) in Figure **4**, the peak of the noise level is cut down, as illustrated by a solid line (b) in Figure **4**, thereby realizing an appropriate sound eliminating operation.

[0042] However, where the control speaker **1** has a nonlinear characteristic in the vicinity of such a low frequency, if the input level exceeds a threshold level Ls, the output sound pressure is saturated (see Figure **5**) while the distortion increases considerably (see Figure **6**), as illustrated in the input-output sound pressure characteristic of Figure **5** and the input-output sound pressure distortion characteristic of Figure **6**. In such a case, if noise (corresponding to the broken line (a) in Figure **4**) whose spectrum at the error detector (microphone) **2** includes signals in the vicinity of the low frequency f1, as illustrated by the broken line (a) in Figure **7**, is processed with the conventional adaptive filter **4**, a sufficient sound elimination cannot be realized because the control sound is saturated at the frequency f1. It may rather lead to generation of a higher harmonic wave distortion at a frequency twice or three times the frequency f1, as illustrated by a solid line (b) in Figure **7**, thereby creating new noise. The distortion may act as an error signal, thereby causing an adverse effect such as making the operation of the adaptive filter **4** unstable.

[0043] In view of this, in the present embodiment, the digital filters **7** and **8** are set to have a band limiting characteristic with a passband characteristic as illustrated in Figure **8** in the low frequency region where the output of the control speaker **1** is reduced (e.g., the frequency region where the frequency is less than or equal to the lower limit reproducible frequency f_L of the control speaker **1**). Under such a setting, the output signal of the adaptive filter **4** is inverted by the phase inverter **10** and processed by the digital filter **8** so as to obtain an error signal, while processing the output signal of the noise detector **3** by the digital filter **7** and inputting the processed signal as a reference signal to the coefficient update calculator **9**. The coefficient update calculator **9** performs a calculation according to Expression (2) to be described later, using an algorithm similar to that of the coefficient update calculator **6**. Then, the coefficient of the adaptive filter **4** is updated by both of the coefficient update calculators **6** and **9** using an update calculation according to Expression (3) to be described later.

[0044] With the above-described structure, the coefficient update calculator **9** operates so as to reduce the output signal of the digital filter **7**, whereby the increase in the coefficient gain of the adaptive filter **4** is suppressed in the low frequency region as illustrated by the solid line (b) in Figure **9**. A broken line (a) in Figure **9** is a coefficient gain of the adaptive filter **4** which is obtained by using only the coefficient update calculator **6**, illustrated in Figure **3** for updating the coefficient of the adaptive filter **4**.

[0045] As a result of the above-described suppression of the increase in the coefficient gain in the low frequency region, an excessive low frequency signal is prevented from being input to the control speaker **1**, thereby performing a stable noise control within the low frequency reproducibility of the control speaker **1** without inappropriately performing a control at the frequency f1, as illustrated by a solid line (b) in Figure **10**. A broken line (a) in Figure **10** corresponds to the broken line (a) in Figures **4** and **7**.

[0046] Moreover, as compared to the conventional structure described above with reference to Figure **22**, where an auxiliary adaptive filter is used, the amount of hardware to be used and the amount of calculation to be performed are reduced with the structure illustrated in Figure **1**.

[0047] Expressions (1)-(3) used in the above description are as follows:

$$\Delta W_j = \mu \cdot e_j \cdot R_j \quad (1)$$

$$\Delta U_j = \nu \cdot v_j \cdot S_j \quad (2)$$

$$W_{j+1} = W_j + \Delta W_j + \Delta U_j \quad (3)$$

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where

$$R_j = (r_j, r_{j-1}, ..., r_{j-n-1}),$$

$$W_j = (w(1)_j, w(2)_j, ..., w(n)_j), \text{ and}$$

$$S_j = (s_j, s_{j-1}, ..., s_{j-n-1})^T.$$

[0048] In these expressions, ΔW_j denotes an output signal vector of the coefficient update calculator **6**, ΔU_j an output signal vector of the coefficient update calculator **9**, W_j a coefficient vector of the adaptive filter **4**, R_j an output vector of the digital filter **5**, S_j an output signal vector of the digital filter **7**, e_j an output signal of the error detector, and v_j an output signal of the digital filter **8**, all at time j. Moreover, it denotes the order of the adaptive filter **4**, and μ and ν are size parameters for a coefficient update step.

[0049] In the above description, the phase inverter **10** is connected between the adaptive filter **4** and the digital filter **8**. Functions and effects similar to those described above are also obtained by the structure as illustrated in Figure **11**, where the phase inverter **10** is connected between the noise detector **3** and the digital filter **7**. Moreover, functions and effects similar to those described above are also obtained by the structure as illustrated in Figure **12**, where the phase inverter **10** is connected to the output of the coefficient update calculator **9**, or by another structure where the phase inverter **10** is connected to the output of the digital filter **8** or the digital filter **7**. Elements in the block diagrams of Figures **11** and **12** corresponding to those shown in Figure **1** have like reference numerals, and will not be further described here.

Embodiment 2

[0050] A noise control system according to Embodiment 2 of the present invention will be described with reference to Figure **13**.

[0051] Figure **13** is a block diagram illustrating a structure of the noise control system of this embodiment. Elements in the block diagram of Figure **13** corresponding to those illustrated in Embodiment **1** with reference to, e.g., Figure **1** have like reference numerals, and will not be further described below.

[0052] According to the present embodiment, the update frequency at which the coefficient update calculation is performed by the coefficient update calculator **6** is increased while the low frequency component of the output of the adaptive filter **4** is small and the control speaker **1** is operating in the linear region. On the other hand, the update frequency at which the coefficient update calculation is performed by the coefficient update calculator **9** is increased, when the law frequency component of the output of the adaptive filter **4** increases and the control speaker **1** enters the non-linear region, so as to perform a coefficient update calculation which suppresses the filter gain in the low frequency region. In this way, it is possible not only to sufficiently reduce the noise even in the low frequency region when the noise level is low, but also to perform a stable noise control even when the noise level in the low frequency region is high.

[0053] Referring to Figure **13**, the illustrated noise control system includes a selector **12** for thinning out the outputs of the coefficient update calculator **6**, another selector **22** for thinning out the outputs of the coefficient update calculator **9**, and a selection control calculator **11** for controlling the operations of the selectors **12** and **22**. The other elements and the functions thereof are similar to those described above in Embodiment **1**. As illustrated in Figure **13**, the selectors **12** and **22**, when in the closed position, transfer the outputs of the coefficient update calculators **6** and **9**, respectively, to the adaptive filter **4**, while selecting no signal (or transferring no signal to the adaptive filter **4**) when in the open position. Thus, by closing each of the selectors **12** and **22** at a predetermined timing (frequency), it is possible to control the update frequency at which the outputs of the coefficient update calculators **6** and **9** are selected and transferred to the adaptive filter **4**, thereby, in effect, thinning out the outputs of the coefficient update calculators **6** and **9** to be transferred to the adaptive filter **4**.

[0054] In order to update the coefficient of the adaptive filter **4**, a large amount of calculation is required. In the structure illustrated in Figure **13**, not all of the calculation is performed for each occurrence of a sampling operation. Instead, a thinned-out update calculation is employed where a coefficient update operation is performed by each of the selectors **12** and **22** once for a number of sampling operations. The respective thinned-out update frequencies (also referred to as the "thinning-out frequencies") for the selectors **12** and **22** are controlled by the selection control calculator **11**.

[0055] For example, while the low frequency component of the output of the adaptive filter **4** is at a small level and the control speaker **1** is operating in the linear region, the selector **12** is closed once for **4** sampling operations to control the adaptive filter by the output of the coefficient update calculator **6**; and the selector **22** is closed once for **16** sampling operations to control the adaptive filter by the output of the coefficient update calculator **9**. Thus, the noise control operation is performed by setting the thinning-out frequency of the selector **22** to be lower than that of the selector **12**.

[0056] In the structure as illustrated in Figure **13**, a low frequency component of the output signal of the adaptive filter **4** is obtained from the digital filter **8** as an output signal thereof. As described above in Embodiment **1**, in the case where the control speaker **1** has a non-linear characteristic in the vicinity of such a low frequency, if the input level exceeds a threshold level Ls, the output sound pressure is saturated (see Figure **5**) while the distortion increases considerably (see Figure **6**), as

illustrated in the input-output sound pressure characteristic of Figure 5 and the input-output sound pressure distortion characteristic of Figure 6. In such a case, if noise (corresponding to the broken line (a) in Figure 4) whose spectrum at the error detector (microphone) 2 includes signals in the vicinity of the low frequency f1, as illustrated by the broken line (a) in Figure 7, is processed with the conventional adaptive filter 4, a sufficient sound elimination cannot be realized because the control mound is saturated at the frequency f1. It may rather lead to generation of a higher harmonic wave distortion at a frequency twice or three times the frequency f1, as illustrated by a solid line (b) in Figure 7, thereby creating new noise. The distortion may act as an error signal, thereby causing an adverse effect such as making the operation of the adaptive filter 4 unstable.

[0057] In view of this, in the present embodiment, the output level of a low frequency component of the output from the digital filter 8 is detected by the selection control calculator 11 and, if the output level exceeds Ls, the thinning-out frequencies of the selectors 12 and 22 are controlled so that the thinning-out frequency of the selector 22 is larger than that of the selector 12. For example, the selector 12 is closed once for 16 sampling operations so as to use the output of the coefficient update calculator 6 for updating the coefficient of the adaptive filter 4 only at this timing, thus controlling the adaptive filter 4 while thinning out the outputs of the coefficient update calculator 6. On the other hand, the selector 22 is closed once for 4 sampling operations so as to use the output of the coefficient update calculator 9 for updating the coefficient of the adaptive filter 4 only at this timing, thus controlling the adaptive filter 4 while thinning out the outputs of the coefficient update calculator 9. As a result, the coefficient of the adaptive filter 4 is updated based on an output of the coefficient update calculator 9 more often than based on an output of the coefficient update calculator 6.

[0058] With the above-described structure, the control speaker 1 operates in the linear region when the low frequency component of the control speaker 1 is at a small level, thereby sufficiently controlling noise which contains a low frequency component (e.g., f1), as illustrated by the solid line (b) in Figure 4. On the other hand, when the level of the low frequency component of the adaptive filter 4 increases and the input to the control speaker 1 exceeds the threshold level Ls to enter the non-linear region, the update operation of the coefficient of the adaptive filter 4 is restricted so as to reduce the low frequency gain. As a result, it is possible to stably control noise without generating a distortion, as illustrated by the solid line (b) in Figure 10.

[0059] Thus, with the noise control system of the present embodiment, it is possible to effectively utilize the linear operability of the control speaker 1 while suppressing the operation thereof in the non-linear region, so as to provide an optimal noise control for low frequency level noise.

Embodiment 3

[0060] A noise control system according to Embodiment 3 of the present invention will be described with reference to Figures 14 and 15.

[0061] Figure 14 is a block diagram illustrating the noise control system of this embodiment. Elements in the block diagram of Figure 14 corresponding to those illustrated in Embodiment 1 with reference to, e.g., Figure 1 have like reference numerals, and will not be further described below.

[0062] According to the present embodiment, the coefficient of the adaptive filter 4 is updated in an optimal manner according to the level of low frequency noise, in view of the output level of the adaptive filter 4 and the linearity of the control speaker 1. In this way, it is possible not only to sufficiently reduce the noise even in the low frequency region when the noise level is low, but also to perform a stable noise control even when the noise level in the low frequency region is high.

[0063] Referring to Figure 14, the illustrated noise control system includes a signal level converter 13 for receiving a signal output from the digital filter 8 as an input. The output signal from the signal level converter 13 is multiplied by the output from the coefficient update calculator 9 at a multiplier 14 which is provided between the coefficient update calculator 9 and the adaptive filter 4. The other elements and the functions thereof are similar to those described above in Embodiment 1.

[0064] In the structure as illustrated in Figure 14, a low frequency component of the output signal of the adaptive filter 4 is obtained from the digital filter 8 as an output signal thereof. As described above in Embodiment 1, in the case where the control speaker 1 has a non-linear characteristic in the vicinity of such a low frequency, if the input level exceeds a threshold level Ls, the output sound pressure is saturated (see Figure 5) while the distortion increases considerably (see Figure 6), as illustrated in the input-output sound pressure characteristic of Figure 5 and the input-output sound pressure distortion characteristic of Figure 6. In such a case, if noise (corresponding to the broken line (a) in Figure 4) whose spectrum at the error detector (microphone) 2 includes signals in the vicinity of the low frequency f1, as illustrated by the broken line (a) in Figure 7, is processed with the conventional adaptive filter 4, a sufficient sound elimination cannot be realized because the control sound is saturated at the frequency f1. It may rather lead to generation of a higher harmonic wave distortion at a frequency twice or three times the frequency f1, as illustrated by a solid line (b) in Figure 7, thereby creating new noise. The distortion may act as an error signal, thereby causing an adverse effect such as making the operation of the adaptive filter 4 unstable.

[0065] In view of this, in the present embodiment, the signal level converter 13 detects the level of the output signal from the digital filter 8, and performs a conversion operation for the detected signal level. In particular, the

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signal level converter **13** converts the level of the signal input thereto (i.e., the output signal from the digital filter **8**) according to the input-output characteristic as illustrated in Figure **15**, which is obtained by normalizing the input-output sound pressure distortion characteristic illustrated in Figure **6**. Then, the level-converted output signal is input to the multiplier **14**, where it is multiplied by the output signal of the coefficient update calculator **9**. As a result, the coefficient of the adaptive filter **4** is updated according to Expression (4) below:

$$W_{j+1} = W_j + \Delta W_j + T(v_j) \cdot \Delta U_j \qquad (4)$$

where $T(v_j)$ denotes the input-output characteristic of the signal level converter **13** as illustrated in Figure **15**.

[0066] With such a structure, in a region where the control speaker **1** operates linearly and the distortion thereof is small, the output signal of the coefficient update calculator **9** is multiplied by a small value which is output from the signal level converter **13**. Thus, the output (the calculation result) from the coefficient update calculator **9** has substantially no influence on the update operation of the coefficient of the adaptive filter **4**, so that the coefficient of the adaptive filter **4** is updated according to the output from the coefficient update calculator **6**. Moreover, since the control speaker **1** operates in the linear region, it is possible to sufficiently control noise which contains a low frequency component (e.g., f1), as illustrated by the solid line (b) in Figure **4**.

[0067] On the other hand, when the level of the low frequency component of the adaptive filter **4** increases and the input to the control speaker **1** exceeds the threshold level Ls to enter the non-linear region, the distortion thereof increases. In such a case, a multiplier factor is set by the signal level converter **13** according to the level of the low frequency output from the control speaker **1**, and the output signal of the coefficient update calculator **9** is multiplied by the multiplier factor. As a result, the coefficient of the adaptive filter **4** is updated based on the output (the calculation result) from the coefficient update calculator **9** after the multiplication operation. Thus, a low frequency gain of the adaptive filter **4** is suppressed so as to perform an optimal and stable noise control within the low frequency reproducibility of the control speaker **1** without inappropriately performing a control at the frequency f1, as illustrated by the solid line (b) in Figure **10**.

Embodiment 4

[0068] A noise control system according to Embodiment 4 of the present invention will be described with reference to the figures.

[0069] In Embodiments 1-3 above, a structure including two coefficient update calculators has been illustrated. In this embodiment, a single coefficient update calculator is used, while a low frequency band of the control signal is limited so that the adaptive filter does not generate an excessive control signal for noise having a frequency which is too low for the low band reproducibility of the control speaker, as in Embodiment 1.

[0070] Figure **16** is a block diagram illustrating a structure of the noise control system of this embodiment. Referring to Figure **16**, the noise control system includes a control speaker **1**, an error detection microphone **2** which functions as an error detector, a noise detection microphone **3** which functions as a noise detector, an adaptive filter **4**, a digital filter **5** which approximates the propagation characteristic between the control speaker **1** and the error detection microphone **2**, a coefficient update calculator **6**, digital filters **7** and **8** each having a frequency band limiting characteristic (band limiting filters), and a phase inverter **10** for inverting the output of the adaptive filter **4**. The noise control system of the present embodiment further includes an adder **111** for adding the output of the digital filter **8** and the output of the error detector **2** so as to provide the sum to the coefficient update calculator **6**, and another adder **112** for adding the output of the digital filter **5** and the output of the digital filter **7** so as to provide the sum to the coefficient update calculator **6**.

[0071] With the structure illustrated in Figure **16**, noise generated from a noise source is detected by a noise detector **3**, and a noise source signal is generated based on the detection result. The generated noise source signal is processed by the adaptive filter **4**, so as to output a control signal. A control sound is generated from the control speaker **1** based on the control signal so that the control sound interferes with the noise from the noise source, thereby reducing the noise.

[0072] Moreover, the state of interference between the control sound output from the control speaker **1** and the noise is measured by the error detector (microphone) **2**. The output of the error detector (microphone) **2** should ideally be zero as a result of the noise control. Therefore, the coefficient update calculator **6** performs a coefficient update calculation as previously described in Expression (1) based on a filtered X-LMS method (see Widrow and Stearns, "Adaptive Signal Processing", 1985), or the like, so as to adjust the characteristic of the adaptive filter **4**, such that the output signal of the error detector (microphone) **2** is reduced. This changes the control sound actually generated from the control speaker **1**, thereby further reducing the noise.

[0073] Typically, the frequency characteristic of the control speaker **1** is such that the sound pressure of an output thereof is reduced in a frequency region where the frequency is less than or equal to the lower limit reproducible frequency f_L, as shown in Figure **2**. For example, where noise has a spectrum which includes such a low frequency region, if only the coefficient update calculator **6** is used for updating the coefficient of the adaptive filter **4**, the coefficient gain of the adaptive filter **4** sufficiently reduces (or cancels) the noise in the low frequency region while compensating for the

characteristic of the control speaker **1**, thereby converging into the characteristic as illustrated in Figure **3**, where the gain has an increase in the low frequency region (a region where the frequency is less than or equal to the lower limit reproducible frequency f_L of the control speaker **1**). In such a case, a large low frequency signal is input to the control speaker **1**.

[0074] In a region where the linearity of the control speaker is maintained, even if the noise spectrum at the error detector (microphone) **2** includes signals in the vicinity of a low frequency f1 as illustrated by the broken line (a) in Figure **4**, the peak of the noise level is cut down, as illustrated by the solid line (b) in Figure **4**, thereby realizing an appropriate sound eliminating operation.

[0075] However, where the control speaker **1** has a nonlinear characteristic in the vicinity of such a low frequency, if the input level exceeds a threshold level Ls, the output sound pressure is saturated (see Figure **5**) while the distortion increases considerably (see Figure **6**), as illustrated in the input-output sound pressure characteristic of Figure **5** and the input-output sound pressure distortion characteristic of Figure **6**. In such a case, if noise (corresponding to the broken line (a) in Figure **4**) whose spectrum at the error detector (microphone) **2** includes signals in the vicinity of the low frequency f1, as illustrated by the broken line (a) in Figure **7**, is processed with the conventional adaptive filter **4**, a sufficient sound elimination cannot be realized because the control sound is saturated at the frequency f1. It may rather lead to generation of a higher harmonic wave distortion at a frequency twice or three times the frequency f1, as illustrated by the solid line (b) in Figure **7**, thereby creating new noise. The distortion may act as an error signal, thereby causing an adverse effect such as making the operation of the adaptive filter **4** unstable.

[0076] In view of this, in the present embodiment, the digital filters **7** and **8** are set to have a band limiting characteristic with a passband characteristic as illustrated in Figure **17** in the low frequency region where the output of the control speaker **1** is reduced (e.g., the frequency region where the frequency is less than or equal to the lower limit reproducible frequency f_L of the control speaker **1**). Under such a setting, the output signal of the adaptive filter **4** is inverted by the phase inverter **10** and processed by the digital filter **8**. The resulting signal is added to the error detection signal by the adder **111**, and the sum is input to the coefficient update calculator **6**. On the other hand, the output signal of the noise detector **3** is processed by the digital filter **7**. The resulting signal is added to the output signal of the digital filter **5** by the adder **112**, and the sum is input to the coefficient update calculator **6**. The gain in the passband of the digital filter **7** is set to be larger than the output signal level of the digital filter **5**. Similarly, the gain in the passband of the digital filter **8** is set to be larger than the output signal level of the error detector.

[0077] In the present embodiment, the following expressions are satisfied:

$$e_all_j = e_j + v_j, \text{ and}$$

$$r_all_j = R_j + S_j$$

where

e_all denotes an output signal of the adder **111**; and
r_all denotes an output signal of the adder **112**.

[0078] On the other hand, the output ΔW_all_j of the coefficient update calculator **6** can be expressed as follows:

$$\Delta W_all_j = \mu \cdot e_all_j \cdot r_all_j = \mu \cdot (e_j + v_j) \cdot (R_j + S_j).$$

[0079] Since $R_j >> S_j$ and $e_j >> v_j$ in the stopbands of the digital filter **7** and the digital filter **8**, the above expression can be substantially expressed as

$$\Delta W_all_j = \mu \cdot v_j \cdot R_j,$$

and the following calculation

$$W_{j+1} = W_j + \Delta W_all_j$$

is performed. Thus, a positive coefficient update operation is performed.

[0080] On the other hand, since the signal levels in the passbands of the digital filter **7** and the digital filter **8** are such that $R_j < S_j$ and $e_j < v_j$ due to the above-described setting, the above expression can be substantially expressed as

$$\Delta W_all_j = \mu \cdot v_j \cdot S_j,$$

and the following calculation

$$W_{j+1} = W_j + \Delta W_all_j$$

is performed. Thus, a negative coefficient update operation is performed.

[0081] In the above description, the following terms are used:

$$R_j = (r_j, r_{j-1}, \ldots, r_{j-n-1}),$$

$$W_j = (w(1)_j, w(2)_j, \ldots, w(n)_j), \text{ and}$$

$$S_j = (s_j, s_{j-i}, \ldots, s_{j-n-1})^T.$$

[0082] In these expressions, ΔW_all_j denotes an output signal vector of the coefficient update calculator **6**, W_j a coefficient vector of the adaptive filter **4**, R_j an out-

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put vector of the digital filter **5**, S_j an output signal vector of the digital filter **7**, e_j an output signal of the error detector, and v_j an output signal of the digital filter **8**, all at time j. Moreover, n denotes the order of the adaptive filter **4**, and μ is a size parameter for a coefficient update step.

[0083] By the operation of the coefficient update calculator **6** in the above-described structure, an increase in the coefficient gain of the adaptive filter **4** in the passbands of the digital filter **7** and the digital filter **8** is suppressed in the low frequency band, as illustrated by the solid line (b) in Figure **9**. With the structure of the present embodiment, the amount of calculation to be performed and the amount of hardware to be used can be reduced, because only one coefficient update calculator is required. The broken line (a) in Figure **9** is a coefficient gain of the adaptive filter **4** which is obtained by using only the output of the digital filter **5** and the output of the error detector **2** for updating the coefficient of the adaptive filter **4**.

[0084] As a result of the above-described suppression of the increase in the coefficient gain in the low frequency region, an excessive low frequency signal is prevented from being input to the control speaker **1**, thereby performing a stable noise control within the low frequency reproducibility of the control speaker **1** without inappropriately performing a control at the frequency f1, as illustrated by the solid line (b) in Figure **10**. The broken line (a) in Figure **10** corresponds to the broken line (a) in Figures **4** and **7**.

[0085] Moreover, as compared to the conventional structure described above with reference to Figure **22**, where an auxiliary adaptive filter is used, the amount of hardware to be used and the amount of calculation to be performed are reduced with the structure illustrated in Figure **16**.

[0086] In the above description, the phase inverter **10** is connected between the adaptive filter **4** and the digital filter **8**. Functions and effects similar to those described above are also obtained by the structure as illustrated in Figure **18**, where the phase inverter **10** is connected between the noise detector **3** and the digital filter **7**. Moreover, functions and effects similar to those described above are also obtained by a structure where the phase inverter **10** is connected to the output of the digital filter **8** or the digital filter **7**.

[0087] Furthermore, while a structure where the gain in the passbands of the digital filters **7** and **8** is set has been described above, in the case of performing a calculation by using an ordinary digital signal processor, effects similar to those described above may be obtained by a structure as illustrated in Figure **19**, which is provided with further coefficient controllers **113** and **114** which utilize bit shifting, or the like, to set a gain equal to or greater than 1. Specifically, in the structure illustrated in Figure **19**, the coefficient controller **113** having a gain of $b>1$ is provided to the output of the digital filter **8**, and the coefficient controller **114** having a gain of $a>1$ is provided to the output of the digital filter **7**.

[0088] Moreover, in the above description, a structure for increasing the gains of the digital filters **7** and **8** has been illustrated. However, in order to set a relative gain relationship as illustrated in Figure **17**, a coefficient controller **144** having a gain of $1/a<1$ may be provided to the output of the digital filter **5**, while providing another coefficient controller **143** having a gain of $1/b<1$ to the output signal of the error detector **2**, as illustrated in Figure **20**. With such a structure, it is possible to provide the coefficient update calculator **6** with a signal whose frequency band, in which a relatively negative coefficient update is performed, is emphasized.

[0089] Elements in the block diagrams of Figures **18** to **20** corresponding to those described previously with reference to Figure **1** have like reference numerals, and will not be further described here.

Embodiment 5

[0090] A noise control system according to Embodiment 5 of the present invention will be described with reference to Figure **21**.

[0091] Figure **21** is a block diagram illustrating a structure of the noise control system of this embodiment. Elements in the block diagram of Figure **21** corresponding to those illustrated in the previous Embodiments with reference to, e.g., Figure **1** have like reference numerals, and will not be further described below.

[0092] According to the present embodiment, a coefficient update calculation as described above in Embodiment 1 is performed when the low frequency component of the output of the adaptive filter **4** is at a small level and the control speaker **1** is operating in the linear region. On the other hand, a coefficient update calculation which suppresses the filter gain in the low frequency region is performed when the low frequency component of the output of the adaptive filter **4** increases and the control speaker **1** enters the non-linear region. In this way, it is possible not only to sufficiently reduce the noise even in the low frequency region when the noise level is low, but also to perform a stable noise control even when the noise level in the low frequency region is high.

[0093] The noise control system illustrated in Figure **21** includes a selector **121** for selecting one of the output of the digital filter **5** and the output of the digital filter **7**, another selector **122** for selecting one of the output of the digital filter **8** and the output of the error detector **2**, and a selection control calculator **123** for controlling the operations of the selectors **121** and **122**. The other elements and the functions thereof are similar to those described above in Embodiment 1.

[0094] In the structure as illustrated in Figure **21**, a low frequency component of the output signal of the adaptive filter **4** is obtained from the digital filter **8** as an output signal thereof. As described above in Embodiment 1 or Embodiment 4, in the case where the control speaker

1 has a non-linear characteristic in the vicinity of such a low frequency, if the input level exceeds a threshold level Ls, the output sound pressure is saturated (see Figure 5) while the distortion increases considerably (see Figure 6), as illustrated in the input-output sound pressure characteristic of Figure 5 and the input-output sound pressure distortion characteristic of Figure 6. In such a case, if noise (corresponding to the broken line (a) in Figure 4) whose spectrum at the error detector (microphone) 2 includes signals in the vicinity of the low frequency f1, as illustrated by the broken line (a) in Figure 7, is processed with the conventional adaptive filter 4, a sufficient sound elimination cannot be realized because the control sound is saturated at the frequency f1. It may rather lead to generation of a higher harmonic wave distortion at a frequency twice or three times the frequency f1, as illustrated by a solid line (b) in Figure 7, thereby creating new noise. The distortion may act as an error signal, thereby causing an adverse effect such as making the operation of the adaptive filter 4 unstable.

[0095] In view of this, in the present embodiment, the selection control calculator **123** is used to detect the output level of the low frequency component in the output from the digital filter **8**. If the output level exceeds a predetermined level Ls, the selector **122** is controlled by the selection control calculator **123** so as to select the output of the digital filter **8**. The selector **121** is controlled by the selection control calculator **123** so as to select the output of the digital filter **7**. Thus, the coefficient update calculator **6** performs the following calculations

$$\Delta W_all_j = \mu_j \cdot v_j \cdot S_j, \text{ and}$$

$$W_{j+1} = W_j + \Delta W_all_j,$$

and updates the coefficient of the adaptive filter **4** in the negative direction based on the calculation result.

[0096] Otherwise, while the output level of the low frequency component from the digital filter **8** is smaller than the predetermined level Ls, the selection control calculator **123** controls the selector **121** to select the output of the digital filter **5** and the selector **122** to select the output of the error detector **2**. Thus, the coefficient update calculator **6** performs the following calculations

$$\Delta W_all_j = \mu_j \cdot v_j \cdot R_j, \text{ and}$$

$$W_{j+1} = W_j + \Delta W_all_j,$$

and updates the coefficient of the adaptive filter **4** in the positive direction based on the calculation result.

[0097] The symbols such as "W_j" used in the above expressions are the same as those described above in Embodiment 1.

[0098] With the above-described structure, the control speaker **1** operates in the linear region when the low frequency component of the control speaker **1** is at a small level, thereby sufficiently controlling noise which contains a low frequency component (e.g., f1), as illustrated by the solid line (b) in Figure **4**. On the other hand, when the level of the low frequency component of the adaptive filter **4** increases and the input to the control speaker **1** exceeds the threshold level Ls to enter the non-linear region, the update operation of the coefficient of the adaptive filter **4** is restricted so as to reduce the low frequency gain. As a result, it is possible to stably control noise without generating a distortion, as illustrated by the solid line (b) in Figure **10**.

[0099] Thus, with the noise control system of the present embodiment, it is possible to effectively utilize the linear operability of the control speaker **1** while suppressing the operation thereof in the non-linear region, so as to provide an optimal noise control for low frequency level noise.

[0100] In the example illustrated in Figure **21**, one of the output of the digital filter **8** and the output of the error detector **2** is always selected by the selector **122**, while one of the output of the digital filter **5** and the output of the digital filter **7** is always selected by the selector **121**. Alternatively, each of the selectors **121** and **122** may perform a thinning-out operation on the outputs at an appropriate thinning-out frequency.

[0101] For example, when the low frequency component of the output from the digital filter **8** exceeds Ls, the selector **122** may operate to transfer the output of the error detector **2** to the coefficient update calculator **6** only at one timing out of **16** transfer timings, while transferring nothing to the coefficient update calculator **6** at the other transfer timings (thus, the outputs of the error detector **2** to be transferred are thinned out), and to transfer the output of the digital filter **8** to the coefficient update calculator **6** only at one timing out of **4** transfer timings, while transferring nothing to the coefficient update calculator **6** at the other transfer timings (thus, the outputs of the digital filter **8** to be transferred are thinned out). Simultaneously, the selector **121** also operates in a manner similar to that of the selector **122** regarding the selection of the outputs from the digital filters **5** and **7**. In this way, the coefficient of the adaptive filter **4** is updated in the negative direction. The above-described operations of the selectors **121** and **122** and the frequency of such operations (i.e., the thinning-out frequency at which the outputs are thinned out) may be controlled by the selection control calculator **123**.

[0102] In the above description of the preferred embodiments of the invention, the digital filter is set in the low frequency region (e.g., the frequency region where the frequency is less than or equal to the lower limit reproducible frequency f_L of the control speaker **1**) in order to suppress the non-linear distortion of the control speaker **1** in the low frequency region. However, it is understood that the frequency band setting of the present invention is not limited thereto, and the coefficient update operation of the adaptive filter **4** having any frequency band can be suppressed by a method similar

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to that described above.

[0103] For example, where external noise, which cannot be detected by the noise detection microphone **3**, is introduced into the error detection microphone **2**, the correlation between the noise detection signal and the error detection signal is reduced at the frequency of the external noise. In such a case, the noise (external noise) may not be eliminated appropriately, and the adaptive filter **4** may even malfunction to produce abnormal oscillation at the frequency of the external noise. In order to prevent this, the passband of the digital filter may be set to coincide with the frequency of the external noise.

[0104] As described above, with the noise control system of the present invention, the noise detection signal and the adaptive filter output signal are processed by the band limiting digital filters, which have the same characteristic, so as to produce a coefficient update signal in the negative direction from both of the output signals, thereby controlling the adaptive filter used in a noise control calculation. In this way, the present invention prevents an undesired increase in the coefficient gain of the adaptive filter in the band of the above-described digital filter, while realizing a coefficient control of the adaptive filter used in a noise control calculation without having to use additional hardware such as an adaptive filter or an additional calculation process, thereby realizing a stable noise processing operation.

[0105] Moreover, whether or not to perform the negative coefficient update for the adaptive filter is controlled in view of the non-linear characteristic of the noise propagation system or the control sound generator. Thus, it is possible to realize a noise control with no band limitation when the noise signal is small, while stably controlling noise by preventing an increase in the input to the control sound generator when the noise signal is large.

[0106] Various other modifications will be apparent to and can be readily made by those skilled in the art without departing from the scope and spirit of this invention. Accordingly, it is not intended that the scope of the claims appended hereto be limited to the description as set forth herein, but rather that the claims be broadly construed.

Claims

1. A noise control system, comprising:

   a control sound generator for generating a control sound;
   an error detector for detecting an error signal between the control sound and noise;
   a noise detector for detecting a noise source signal;
   an adaptive filter for outputting a control signal; and
   a coefficient updator for updating a coefficient of the adaptive filter, the coefficient updator comprising at least a first digital filter, a first coefficient update calculator, a second digital filter, a phase inverter, a third digital filter, and a second coefficient update calculator,
   wherein the coefficient updator has a function of suppressing an increase in a coefficient gain of the adaptive filter in a predetermined frequency band.

2. A noise control system according to claim 1, wherein the coefficient updator is such that:

   the first digital filter receives, as an input thereto, an output of the noise detector;
   the first coefficient update calculator receives, as inputs thereto, an output of the first digital filter and an output of the error detector;
   the phase inverter inverts the output of the noise detector;
   the second digital filter receives, as an input thereto, an output of the phase inverter;
   the third digital filter receives, as an input thereto, the output of the error detector;
   the second coefficient update calculator receives, as inputs thereto, outputs of the second and third digital filters;
   the first digital filter approximates a propagation characteristic between the control sound generator and the error detector;
   the second and third digital filters have a common passband frequency characteristic;
   the first coefficient update calculator performs a calculation such that the output of the error detector is reduced, and updates the coefficient of the adaptive filter based on the calculation result; and
   the second coefficient update calculator performs a calculation such that the output of the third digital filter is reduced, and updates the coefficient of the adaptive filter based on the output of the coefficient update calculator.

3. A noise control system according to claim 1, wherein the coefficient updator is such that:

   the first digital filter receives, as an input thereto, an output of the noise detector;
   the first coefficient update calculator receives, as inputs thereto, an output of the first digital filter and an output of the error detector;
   the second digital filter receives, as an input thereto, an output of the noise detector;
   the third digital filter receives, as an input thereto, the output of the error detector;
   the second coefficient update calculator receives, as inputs thereto, outputs of the second and third digital filters;
   the phase inverter inverts an output of the sec-

ond coefficient update calculator;
the first digital filter approximates a propagation characteristic between the control sound generator and the error detector;
the second and third digital filters have a common passband frequency characteristic;
the first coefficient update calculator performs a calculation such that the output of the error detector is reduced, and updates the coefficient of the adaptive filter based on the calculation result; and
the second coefficient update calculator performs a calculation such that the output of the third digital filter is reduced, inverts and outputs the calculation result, and updates the coefficient of the adaptive filter based on the output of the second coefficient update calculator.

4. A noise control system according to claim 1, wherein:

the coefficient updator further comprises: a first selection controller for thinning out the outputs of the first coefficient update calculator, a second selection controller for thinning out the outputs of the second coefficient update calculator; and a selection control calculator for receiving an output signal of the third digital filter to control the first and second selection controllers;
the first digital filter receives, as an input thereto, an output of the noise detector;
the first coefficient update calculator receives, as inputs thereto, an output of the first digital filter and an output of the error detector;
the phase inverter inverts an output of the adaptive filter;
the third digital filter receives, as an input thereto, an output of the phase inverter;
the second coefficient update calculator receives, as inputs thereto, outputs of the second and third digital filters;
the first digital filter approximates a propagation characteristic between the control sound generator and the error detector;
the second and third digital filters have a common passband frequency characteristic;
the first coefficient update calculator performs a calculation such that the output of the error detector is reduced;
the second coefficient update calculator performs a calculation such that the output of the third digital filter is reduced; and
when a level of the output signal of the third digital filter exceeds a predetermined value, the selection control calculator updates the coefficient of the adaptive filter by controlling the first and second selection controllers so that the first selection controller performs the thinning-out operation at a thinning-out frequency lower than that of the second selection controller.

5. A noise control system according to claim 1, wherein:

the coefficient updator further comprises: a first selection controller for switching between selecting an output of the first coefficient update calculator and selecting nothing; a second selection controller for switching between selecting an output of the second coefficient update calculator and selecting nothing; and a selection control calculator for receiving an output signal of the third digital filter to control the first and second selection controllers;
the first digital filter receives, as an input thereto, an output of the noise detector;
the first coefficient update calculator receives, as inputs thereto, an output of the first digital filter and an output of the error detector;
the phase inverter inverts an output of the adaptive filter;
the third digital filter receives, as an input thereto, an output of the phase inverter;
the second coefficient update calculator receives, as inputs thereto, outputs of the second and third digital filters;
the first digital filter approximates a propagation characteristic between the control sound generator and the error detector;
the second and third digital filters have a common passband frequency characteristic;
the first coefficient update calculator performs a calculation such that the output of the error detector is reduced;
the second coefficient update calculator performs a calculation such that the output of the third digital filter is reduced; and
when a level of the output signal of the third digital filter exceeds a predetermined value, the selection control calculator updates the coefficient of the adaptive filter by controlling the first and second selection controllers so that the first selection controller is switched to select nothing at a switching operation frequency lower than that at which the second selection controller is switched to select nothing.

6. A noise control system according to claim 1, wherein:

the coefficient updator further comprises: a signal level converter for receiving an output signal of the third digital filter to convert a level of the signal; and a multiplier for multiplying an output of the signal level converter by an output

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of the second coefficient update calculator so as to update the coefficient of the adaptive filter;
the first digital filter receives, as an input thereto, an output of the noise detector;
the first coefficient update calculator receives, as inputs thereto, an output of the first digital filter and an output of the error detector;
the second digital filter receives, as an input thereto, the output of the noise detector;
the phase inverter inverts an output of the adaptive filter;
the third digital filter receives, as an input thereto, an output of the phase inverter;
the second coefficient update calculator receives, as inputs thereto, outputs of the second and third digital filters;
the first digital filter approximates a propagation characteristic between the control sound generator and the error detector;
the second and third digital filters have a common passband frequency characteristic;
the first coefficient update calculator performs a calculation such that the output of the error detector is reduced;
the second coefficient update calculator performs a calculation such that the output of the third digital filter is reduced; and
the signal level converter has an input-output characteristic which is approximated to a characteristic obtained by normalizing an input-distortion characteristic of the control sound generator.

7. A noise control system according to claim 1, wherein the predetermined frequency band exists in a low frequency region.

8. A noise control system according to claim 7, wherein the predetermined frequency band is a frequency region where the frequency is less than or equal to a lower limit reproducible frequency of the control sound generator.

9. A noise control system, comprising:

a control sound generator for generating a control sound;
an error detector for detecting an error signal between the control sound and noise;
a noise detector for detecting a noise source signal;
an adaptive filter for outputting a control signal; and
a coefficient updator for updating a coefficient of the adaptive filter, the coefficient updator comprising at least a first digital filter, a second digital filter, a third digital filter, a coefficient update calculator, a phase inverter, a first adder, and a second adder,
wherein the coefficient updator has a function of suppressing an increase in a coefficient gain of the adaptive filter in a predetermined frequency band.

10. A noise control system according to claim 9, wherein the coefficient updator is such that:

the first digital filter receives, as an input thereto, an output of the noise detector;
the second digital filter receives, as an input thereto, the output of the noise detector;
the first adder receives, as inputs thereto, an output of the first digital filter and an output of the second digital filter;
the second adder receives, as inputs thereto, an output of the error detector and an output of the third digital filter;
the coefficient update calculator receives, as inputs thereto, an output of the first adder and an output of the second adder;
the phase inverter inverts an output of the adaptive filter;
the third digital filter receives, as an input thereto, the output of the phase inverter;
the first digital filter approximates a propagation characteristic between the control sound generator and the error detector;
the second and third digital filters have a common passband frequency characteristic; and
the coefficient update calculator performs a calculation such that the output of the second adder is reduced, and updates the coefficient of the adaptive filter based on the calculation result.

11. A noise control system according to claim 9, wherein the coefficient updator is such that:

the first digital filter receives, as an input thereto, an output of the noise detector;
the phase inverter inverts the output of the noise detector;
the second digital filter receives, as an input thereto, the output of the phase inverter;
the first adder receives, as inputs thereto, an output of the first digital filter and an output of the second digital filter;
the second adder receives, as inputs thereto, an output of the error detector and an output of the third digital filter;
the coefficient update calculator receives, as inputs thereto, an output of the first adder and an output of the second adder;
the third digital filter receives, as an input thereto, an output of the adaptive filter;

the first digital filter approximates a propagation characteristic between the control sound generator and the error detector;
the second and third digital filters have a common passband frequency characteristic; and
the coefficient update calculator performs a calculation such that the output of the second adder is reduced, and updates the coefficient of the adaptive filter based on the calculation result.

12. A noise control system according to claim 9, wherein:

the coefficient updator further comprises: a first coefficient controller for multiplying an output of the second digital filter by a first coefficient factor; and a second coefficient controller for multiplying an output of the third digital filter by a second coefficient factor;
the first digital filter receives, as an input thereto, an output of the noise detector;
the second digital filter receives, as an input thereto, the output of the noise detector;
the first adder receives, as inputs thereto, an output of the first digital filter and an output of the first coefficient controller;
the second adder receives, as inputs thereto, an output of the error detector and an output of the second coefficient controller;
the coefficient update calculator receives, as inputs thereto, an output of the first adder and an output of the second adder;
the phase inverter inverts an output of the adaptive filter;
the third digital filter receives, as an input thereto, the output of the phase inverter;
each of the first coefficient factor and the second coefficient factor is set to be equal to or more than 1;
the first digital filter approximates a propagation characteristic between the control sound generator and the error detector;
the second and third digital filters have a common passband frequency characteristic; and
the coefficient update calculator performs a calculation such that the output of the second adder is reduced, and updates the coefficient of the adaptive filter based on the calculation result.

13. A noise control system according to claim 12, wherein the first coefficient controller is set so that in a passband of the second digital filter, the output of the first coefficient controller is larger than an output signal of the first digital filter.

14. A noise control system according to claim 12, wherein the second coefficient controller is set so that in a passband of the third digital filter, the output of the second coefficient controller is larger than an output signal of the error detector.

15. A noise control system according to claim 9, wherein:

the coefficient updator further comprises: a first coefficient controller for multiplying an output of the first digital filter by a first coefficient factor; and a second coefficient controller for multiplying an output of the error detector by a second coefficient factor;
the first digital filter receives, as an input thereto, an output of the noise detector;
the second digital filter receives, as an input thereto, the output of the noise detector;
the first adder receives, as inputs thereto, an output of the first coefficient controller and an output of the second digital filter;
the second adder receives, as inputs thereto, an output of the second coefficient controller and an output of the third digital filter;
the coefficient update calculator receives, as inputs thereto, an output of the first adder and an output of the second adder;
the phase inverter inverts an output of the adaptive filter;
the third digital filter receives, as an input thereto, the output of the phase inverter;
each of the first coefficient factor and the second coefficient factor is set to be less than or equal to 1;
the first digital filter approximates a propagation characteristic between the control sound generator and the error detector;
the second and third digital filters have a common passband frequency characteristic; and
the coefficient update calculator performs a calculation such that the output of the second adder is reduced, and updates the coefficient of the adaptive filter based on the calculation result.

16. A noise control system according to claim 15, wherein the first coefficient controller is set so that in a passband of the second digital filter, the output of the first coefficient controller is smaller than an output signal of the first digital filter.

17. A noise control system according to claim 15, wherein the second coefficient controller is set so that in a passband of the third digital filter, the output of the second coefficient controller is smaller than an output signal of the error detector.

18. A noise control system according to claim 9,

wherein the predetermined frequency band exists in a low frequency region.

19. A noise control system according to claim 18, wherein the predetermined frequency band is a frequency region where the frequency is less than or equal to a lower limit reproducible frequency of the control sound generator.

20. A noise control system according to claim 9, wherein the predetermined frequency band exists in a frequency region where there is a correlation between an output signal of the noise detector and an output signal of the error detector.

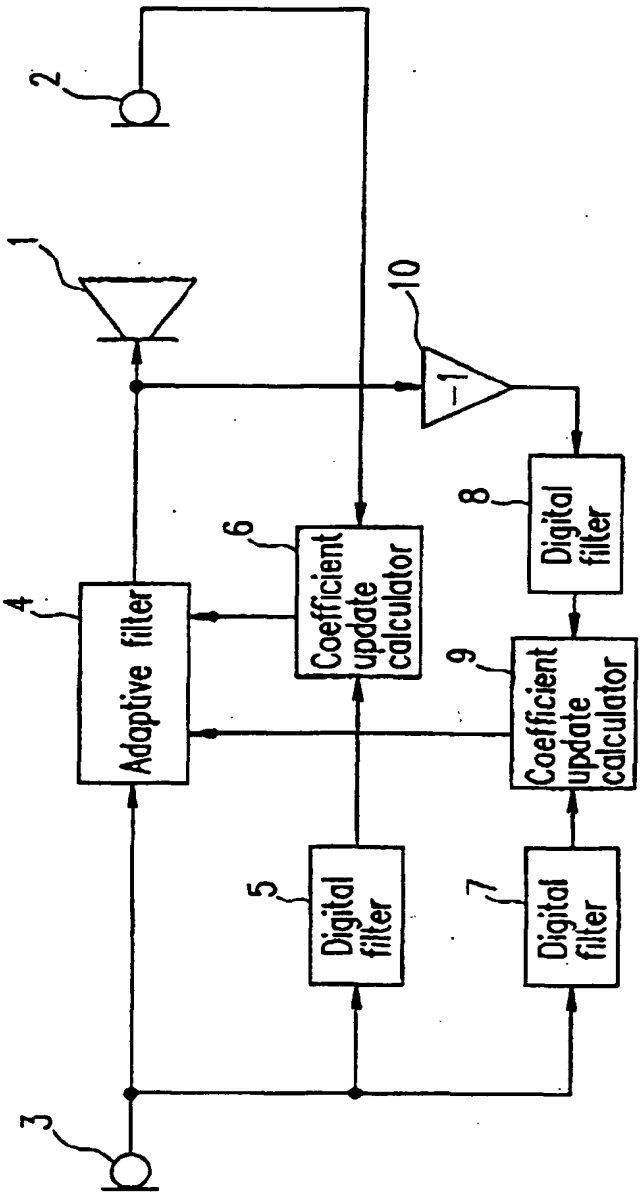

FIG. 1

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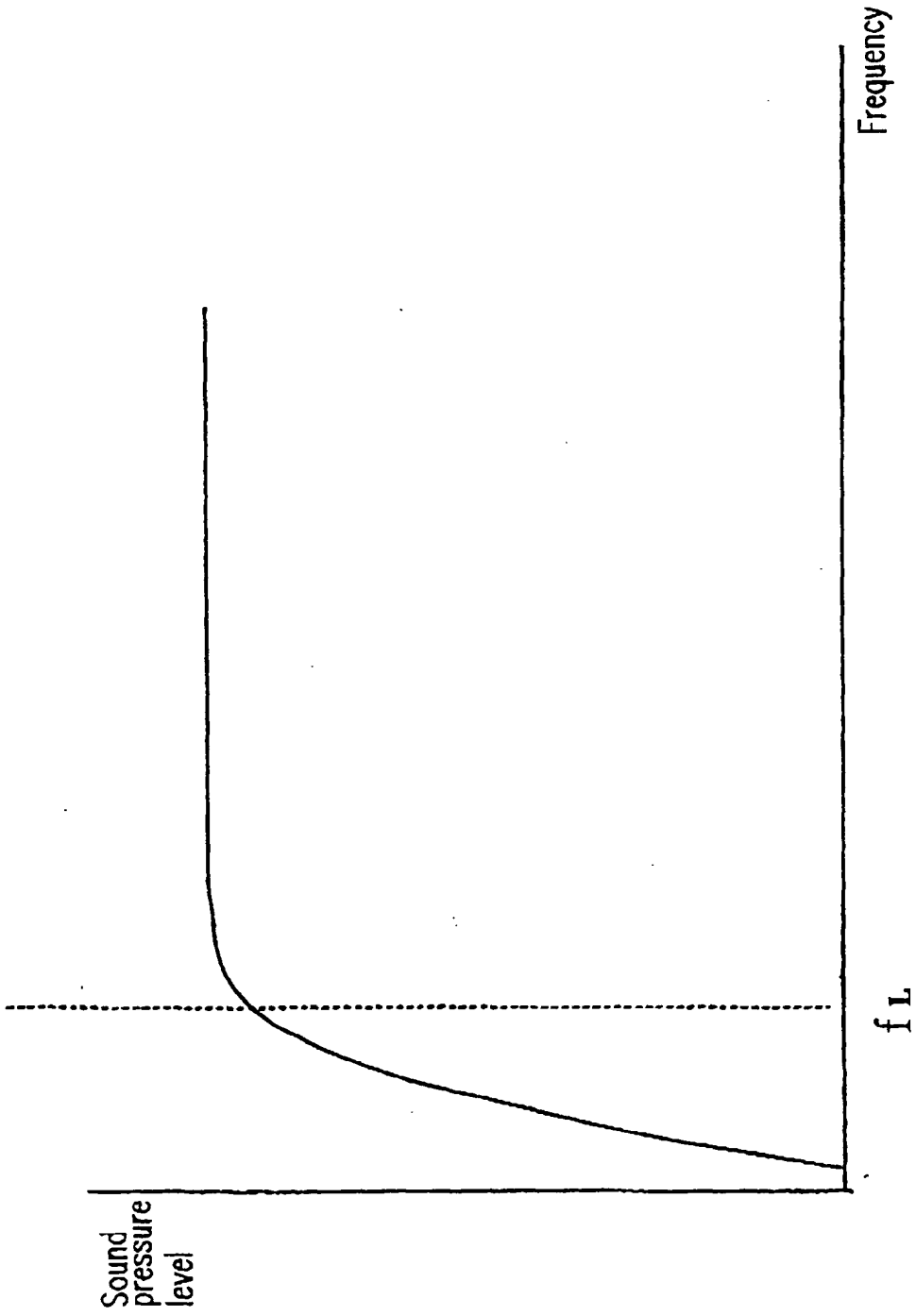

FIG. 2

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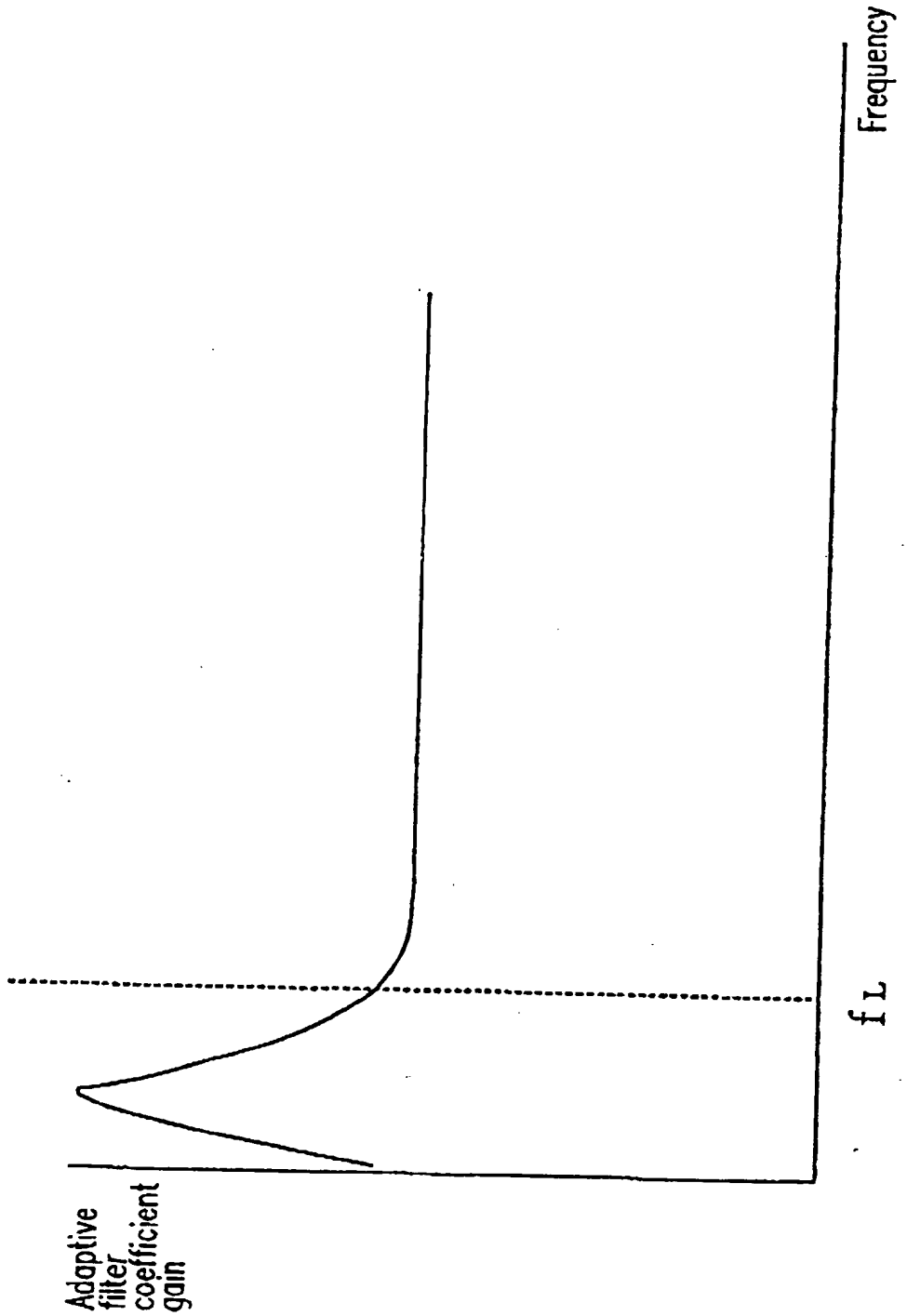

FIG. 3

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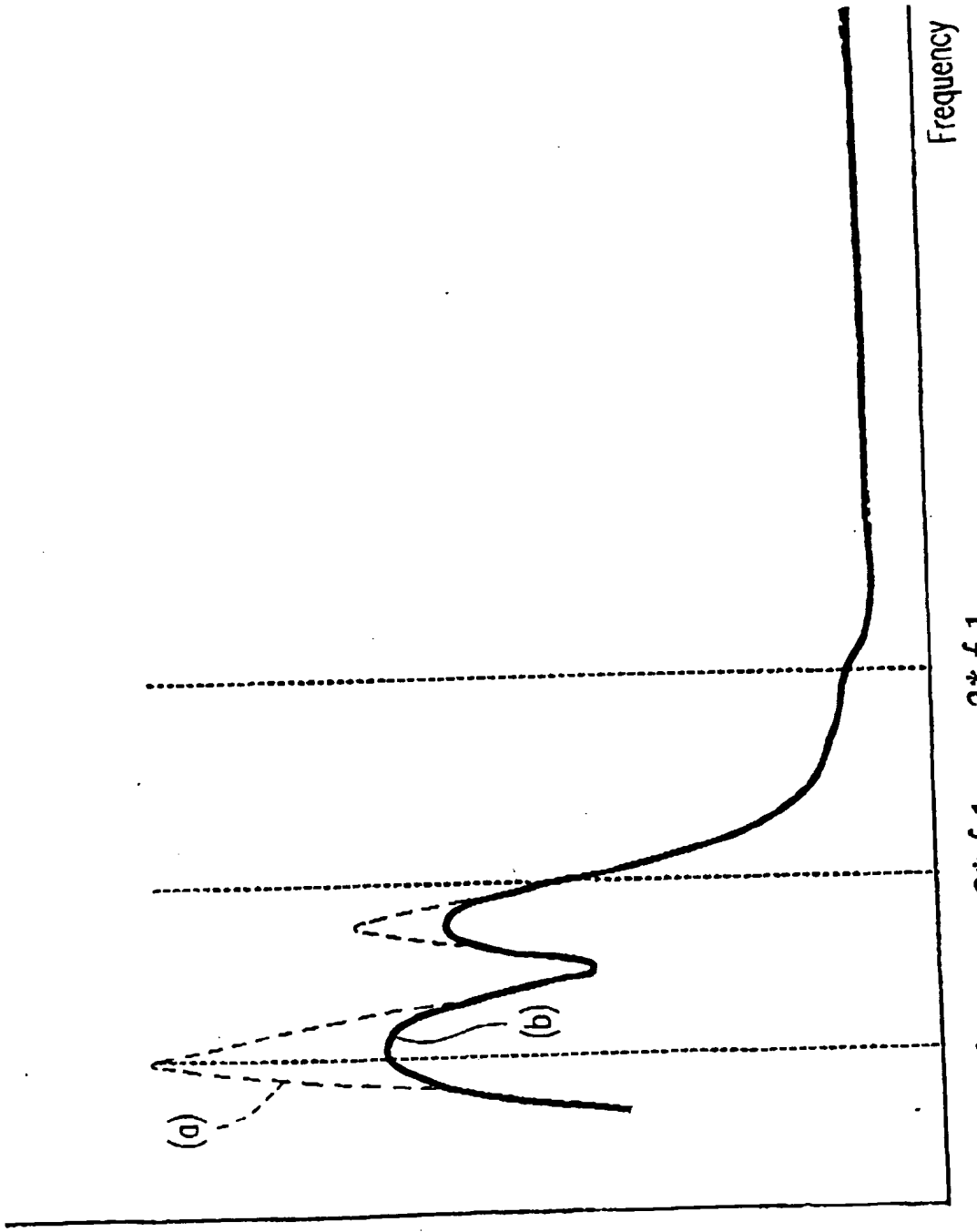

FIG. 4

FIG. 5

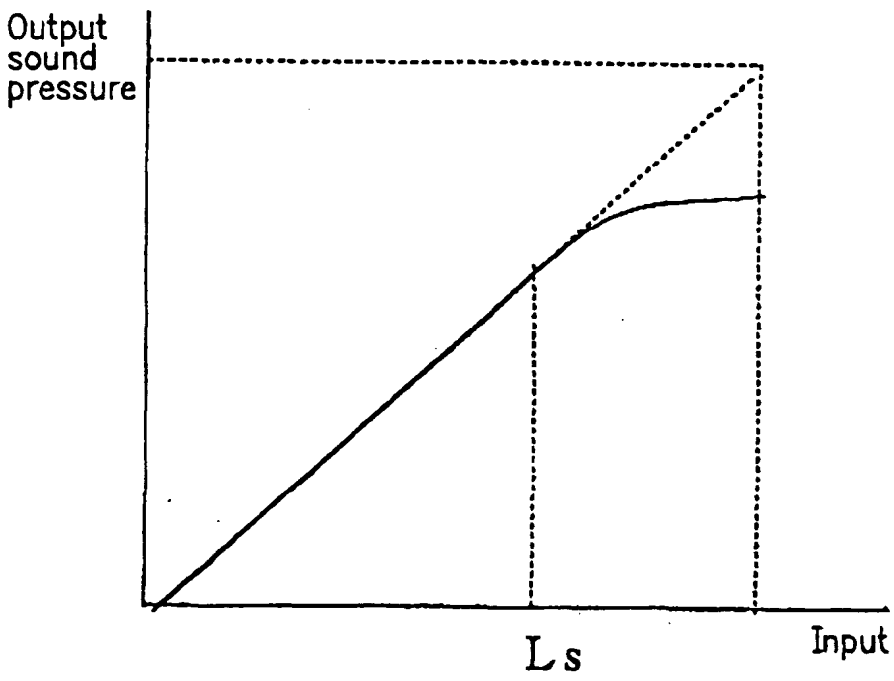

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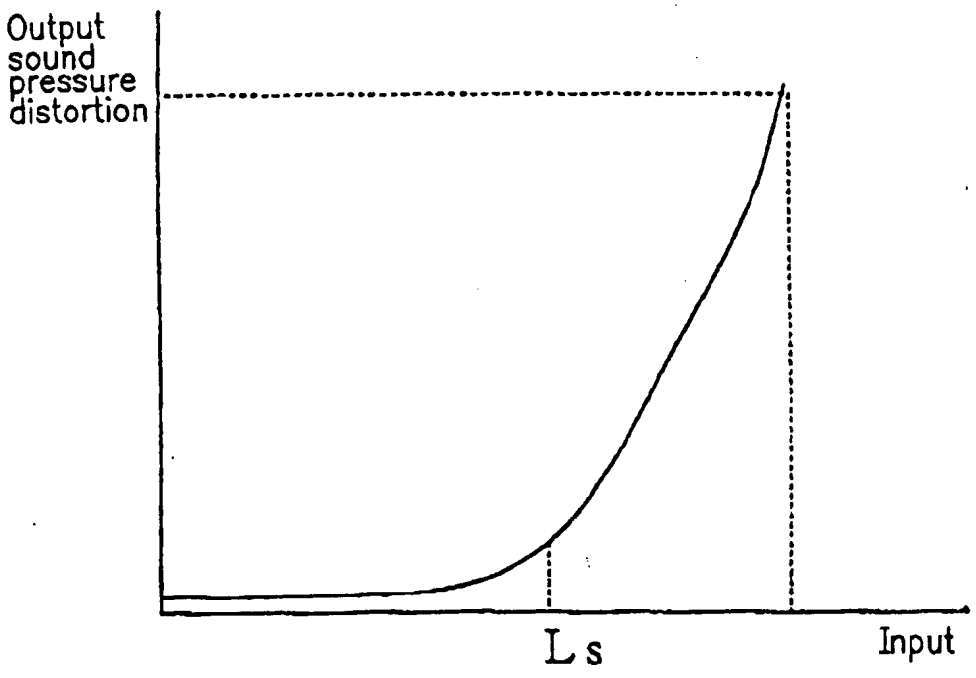
FIG. 6



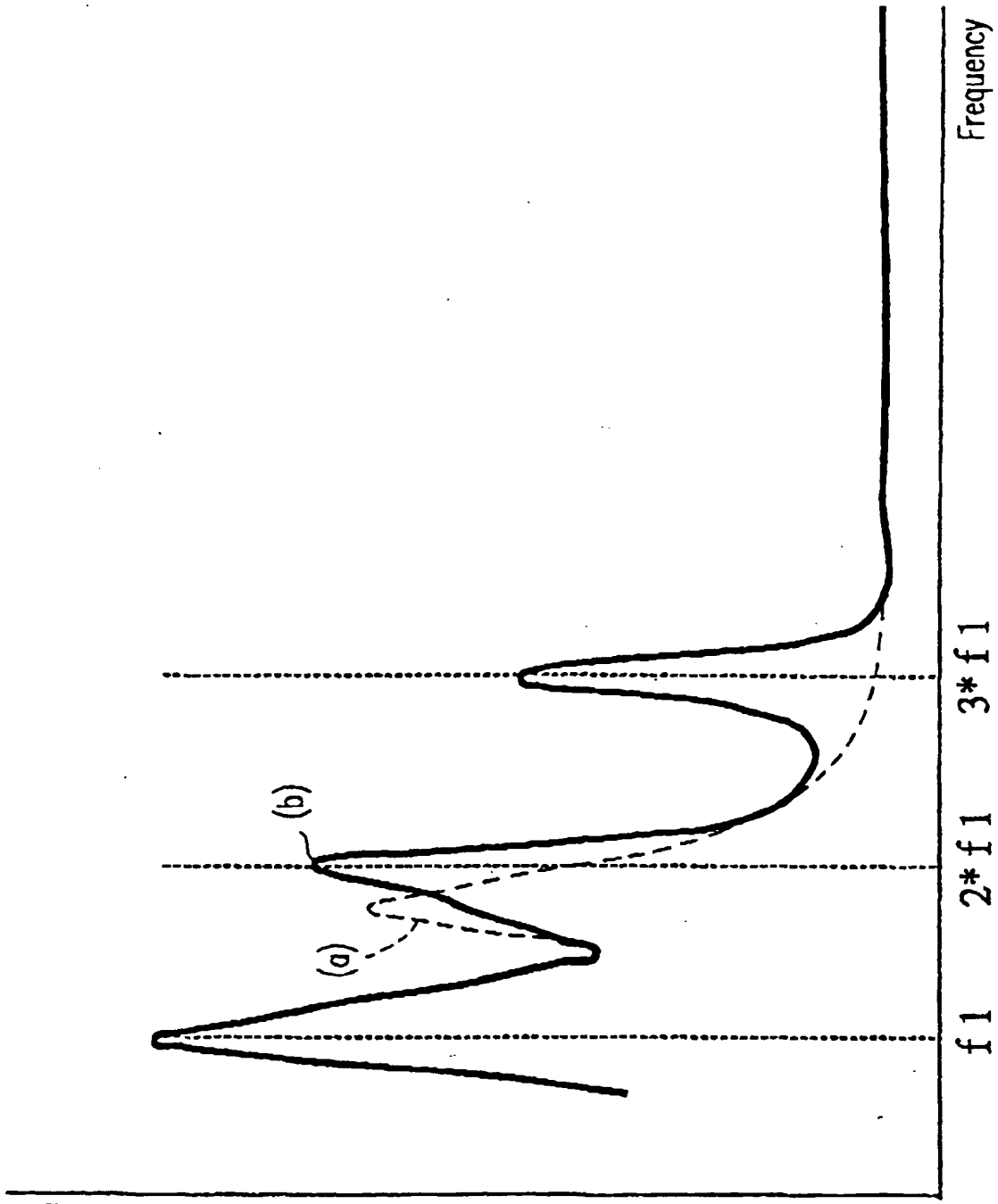


FIG. 7

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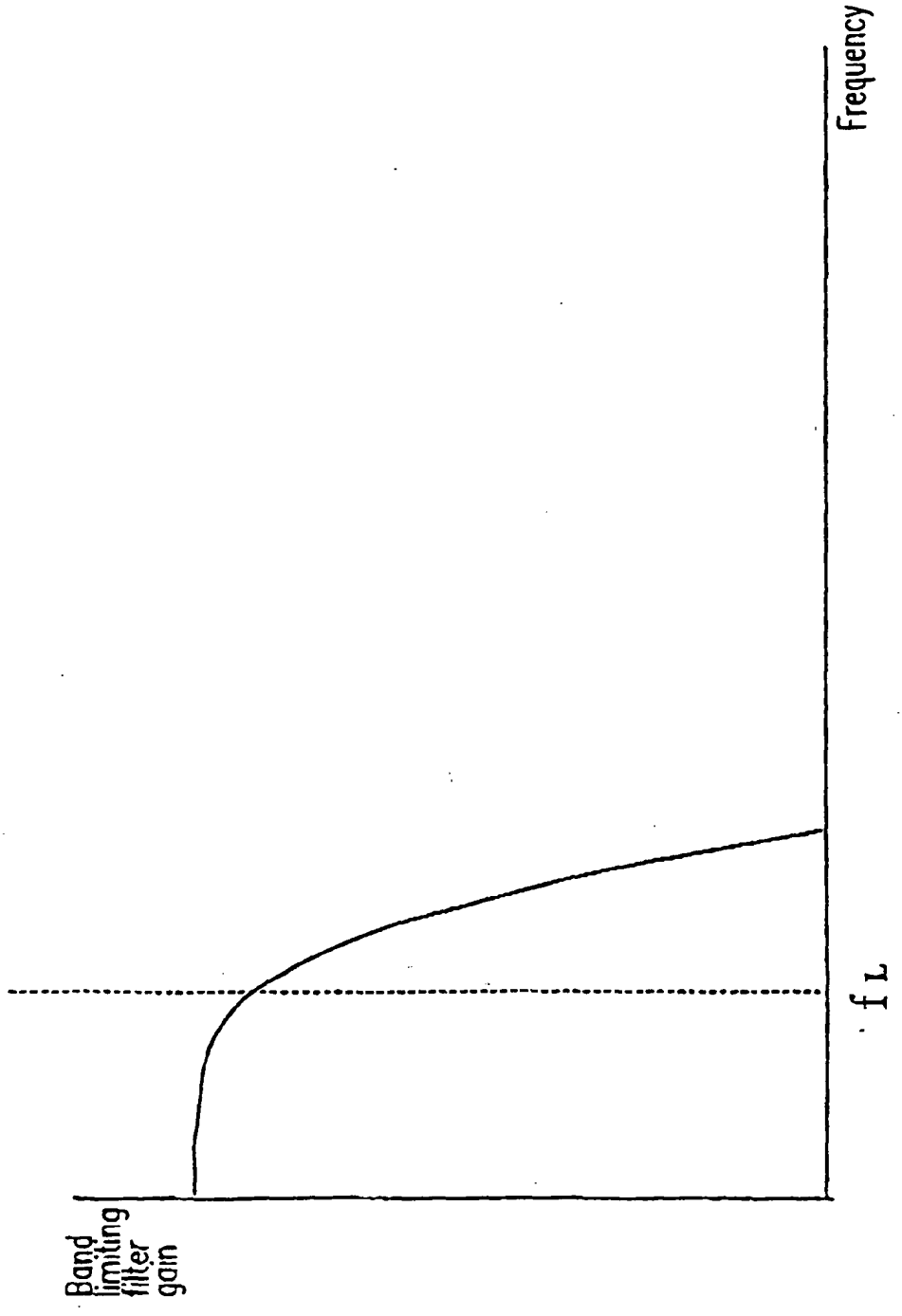
FIG. 8



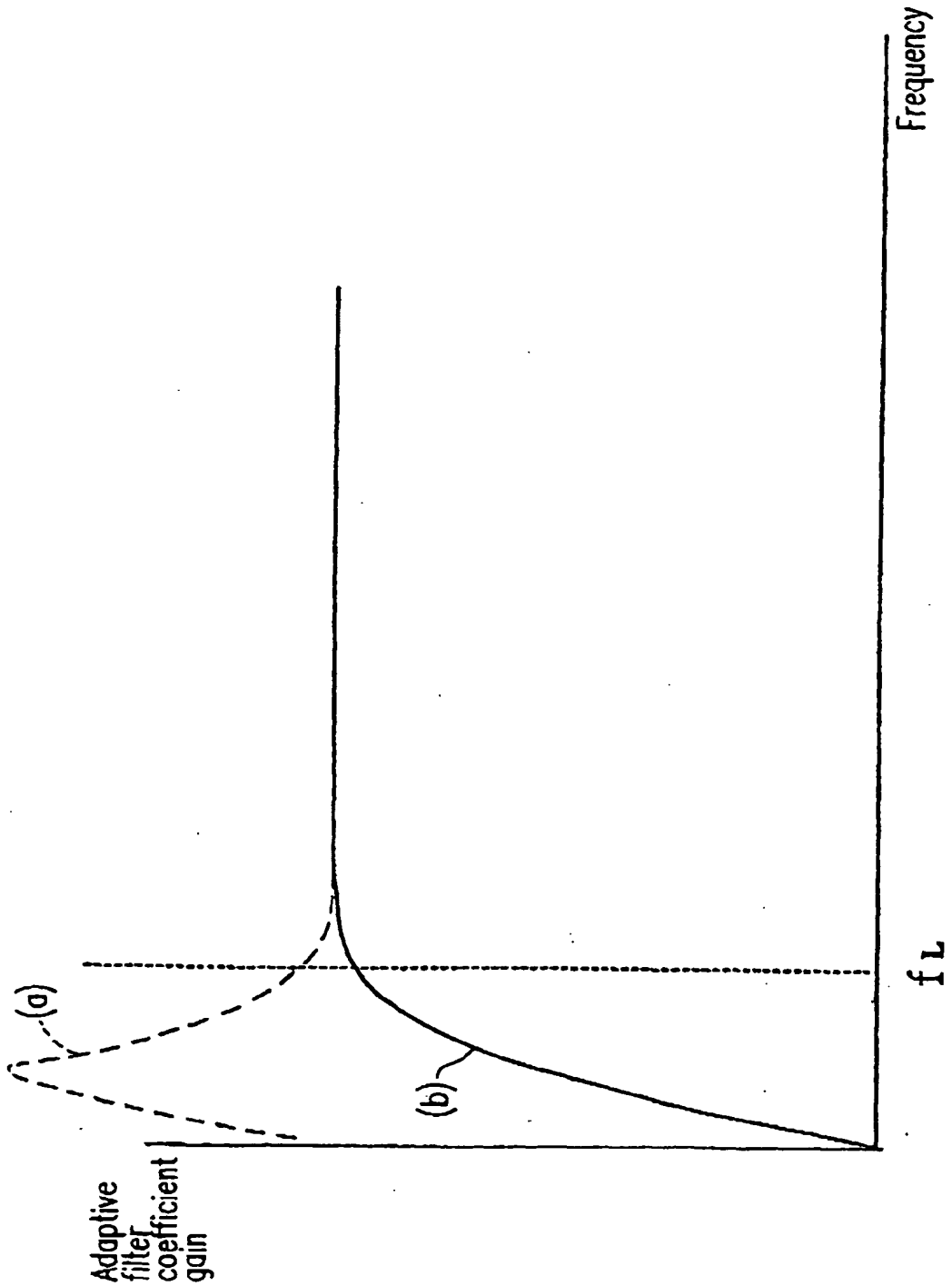


FIG. 9

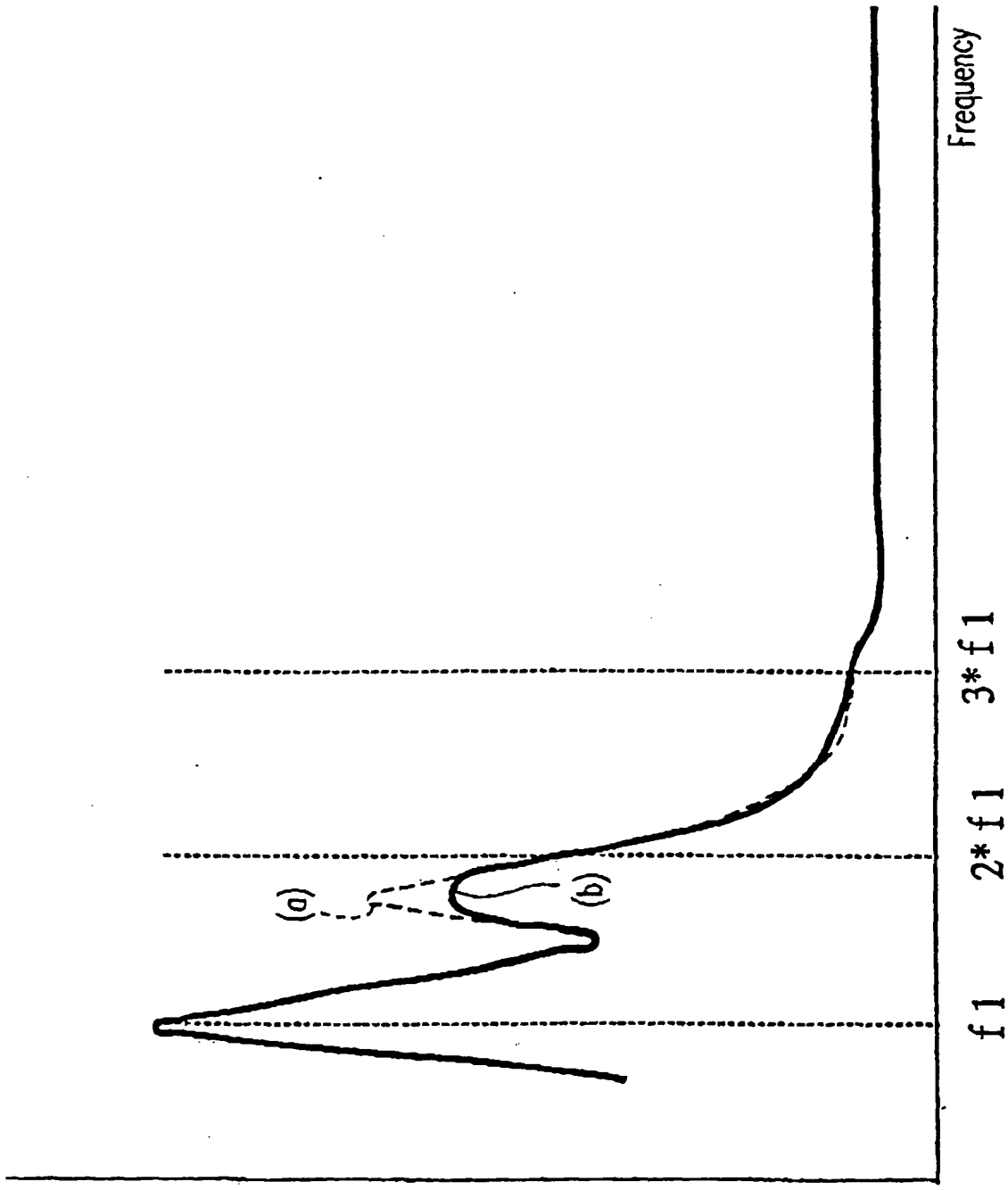


FIG. 10

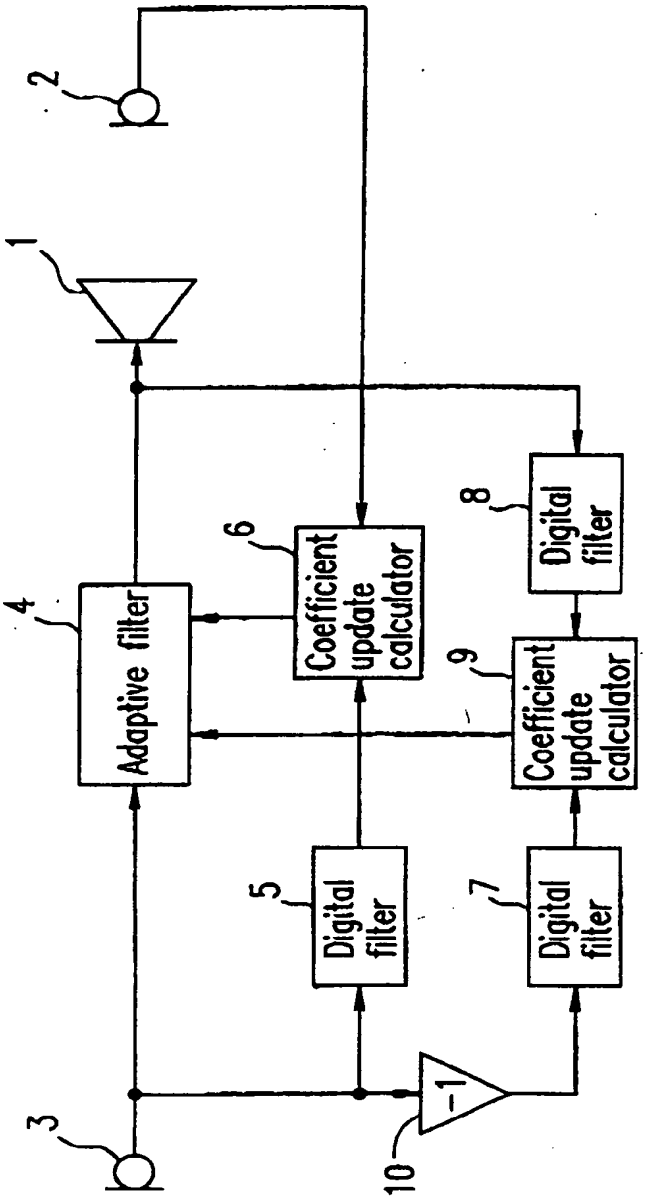


FIG. 11

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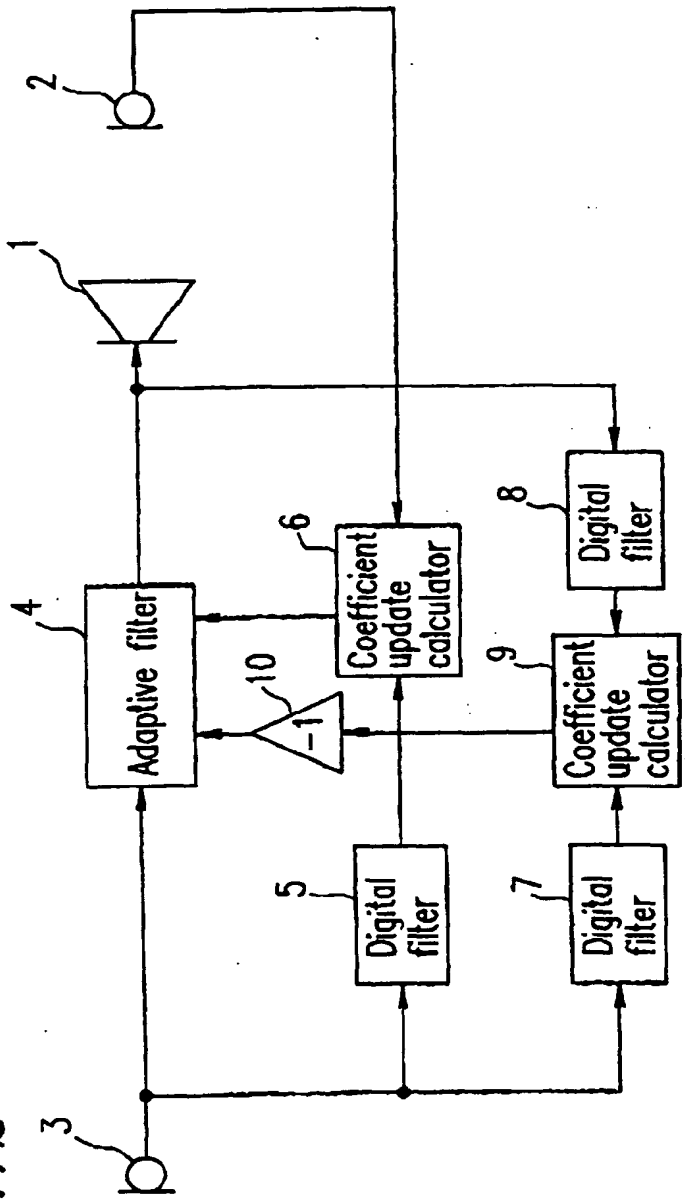
2
1
8
Digital filter
6
Coefficient update calculator
4
Adaptive filter
10
-1
9
Coefficient update calculator
5
Digital filter
7
Digital filter
3

FIG. 12

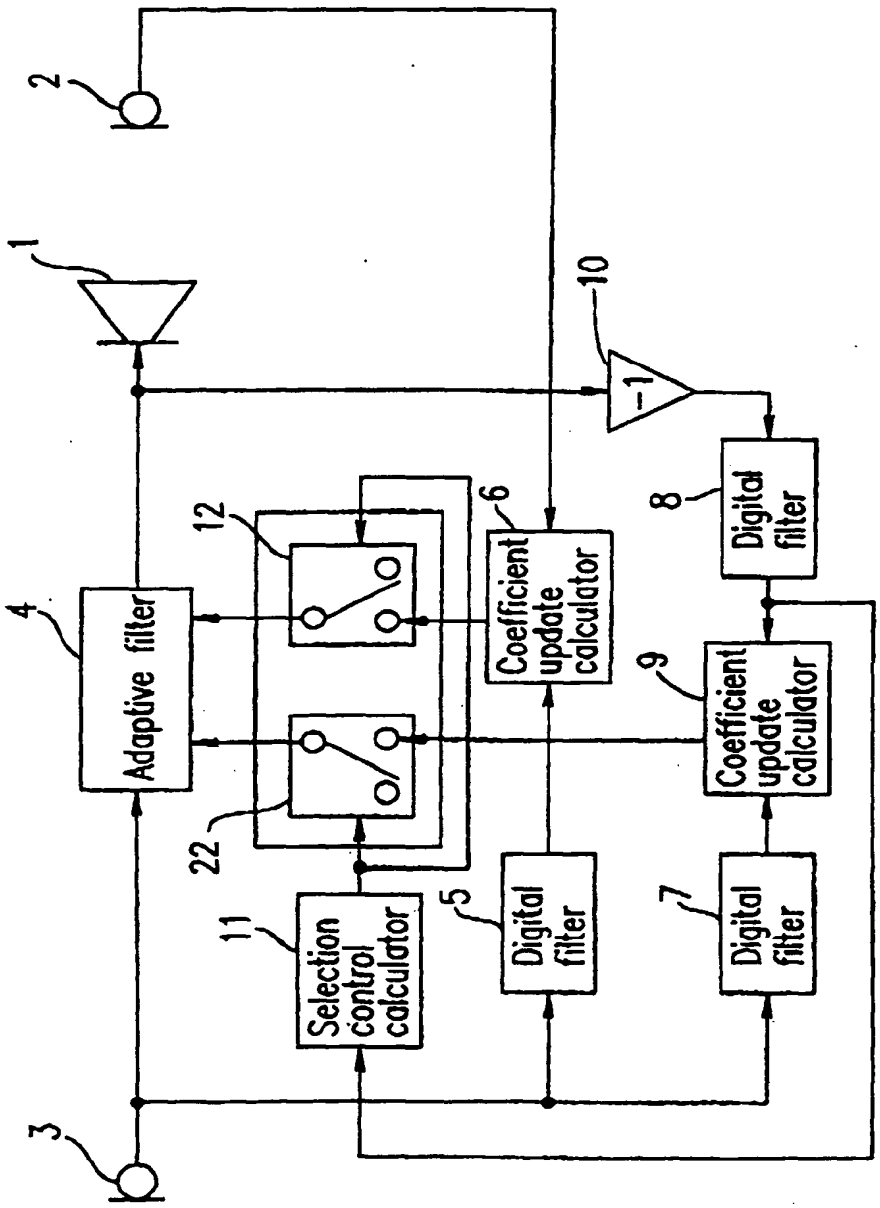

FIG. 13

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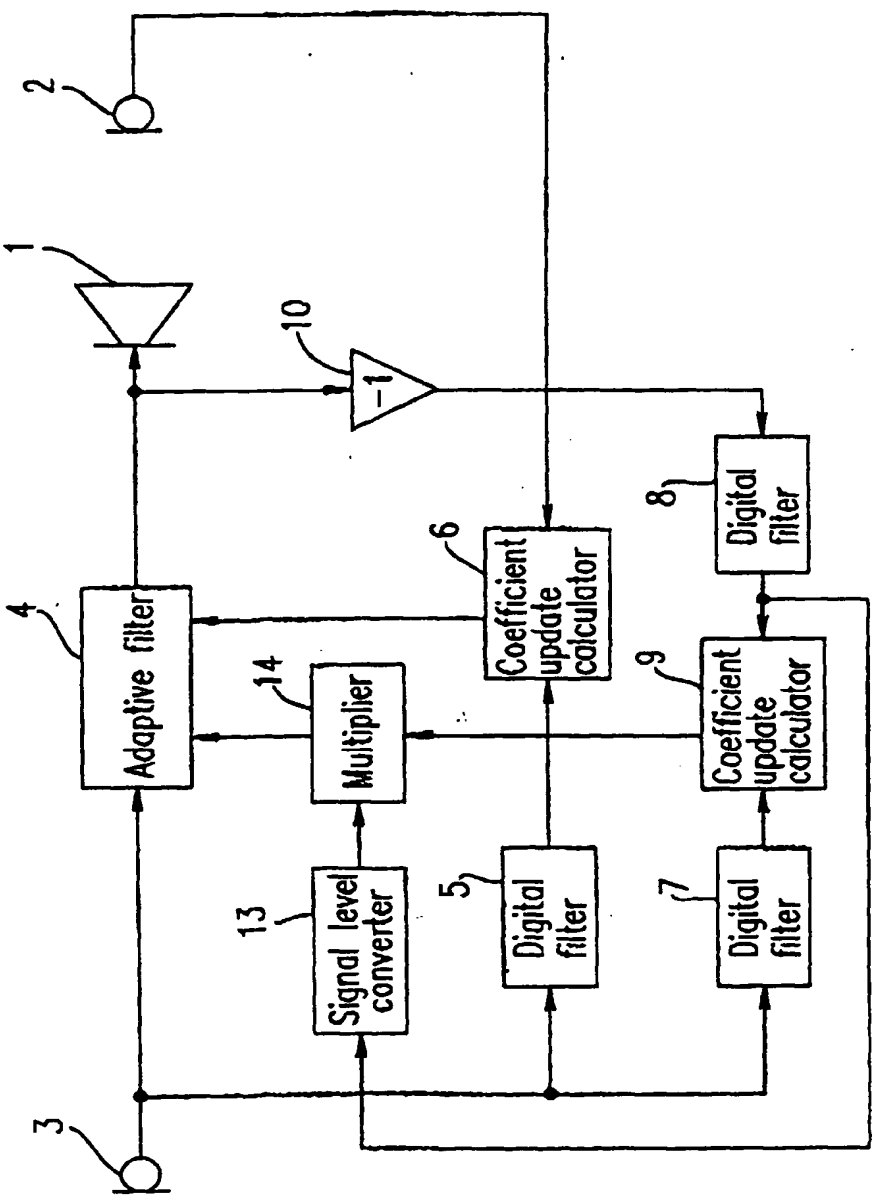
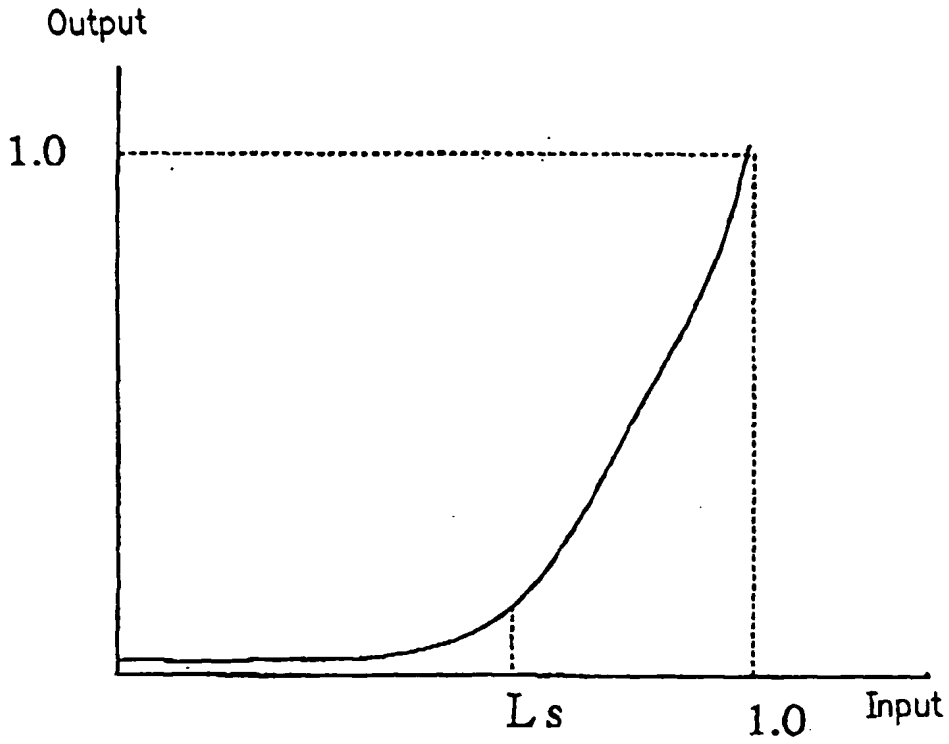

2
1
10
-1
8
Digital filter
6
Coefficient update calculator
4
Adaptive filter
14
Multiplier
9
Coefficient update calculator
13
Signal level converter
5
Digital filter
7
Digital filter
3

FIG. 14

FIG. 15



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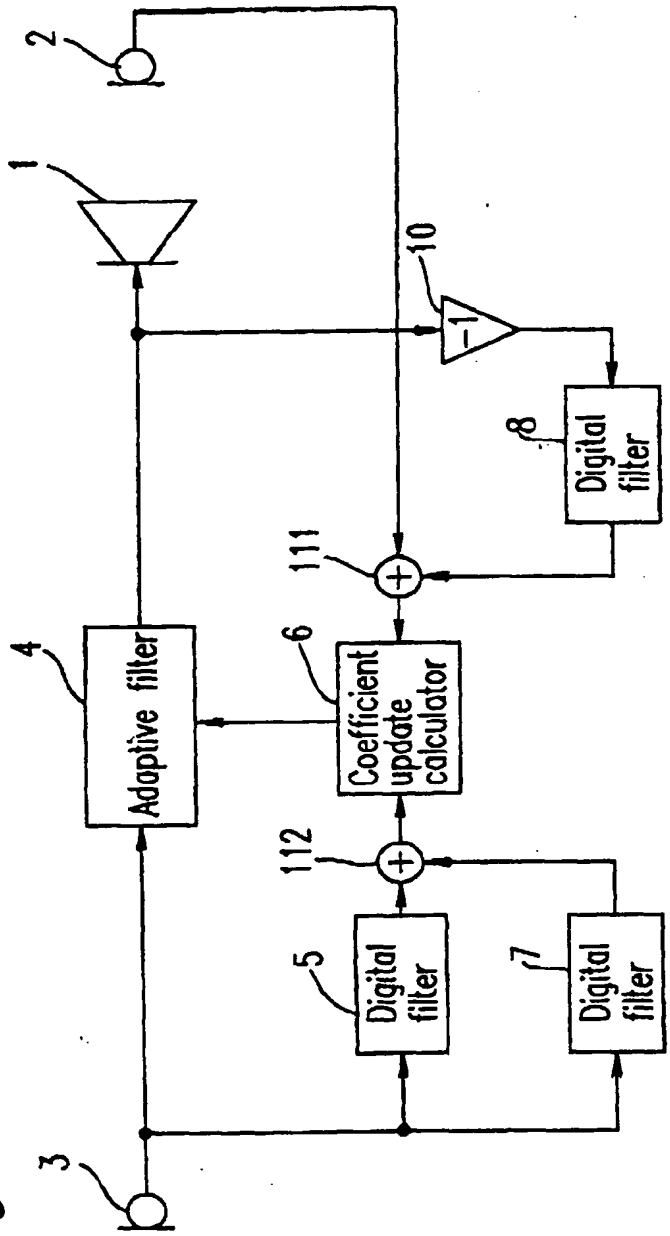
2
1
10
-1
8
Digital filter
111
4
Adaptive filter
6
Coefficient update calculator
112
5
Digital filter
7
Digital filter
3

FIG. 16

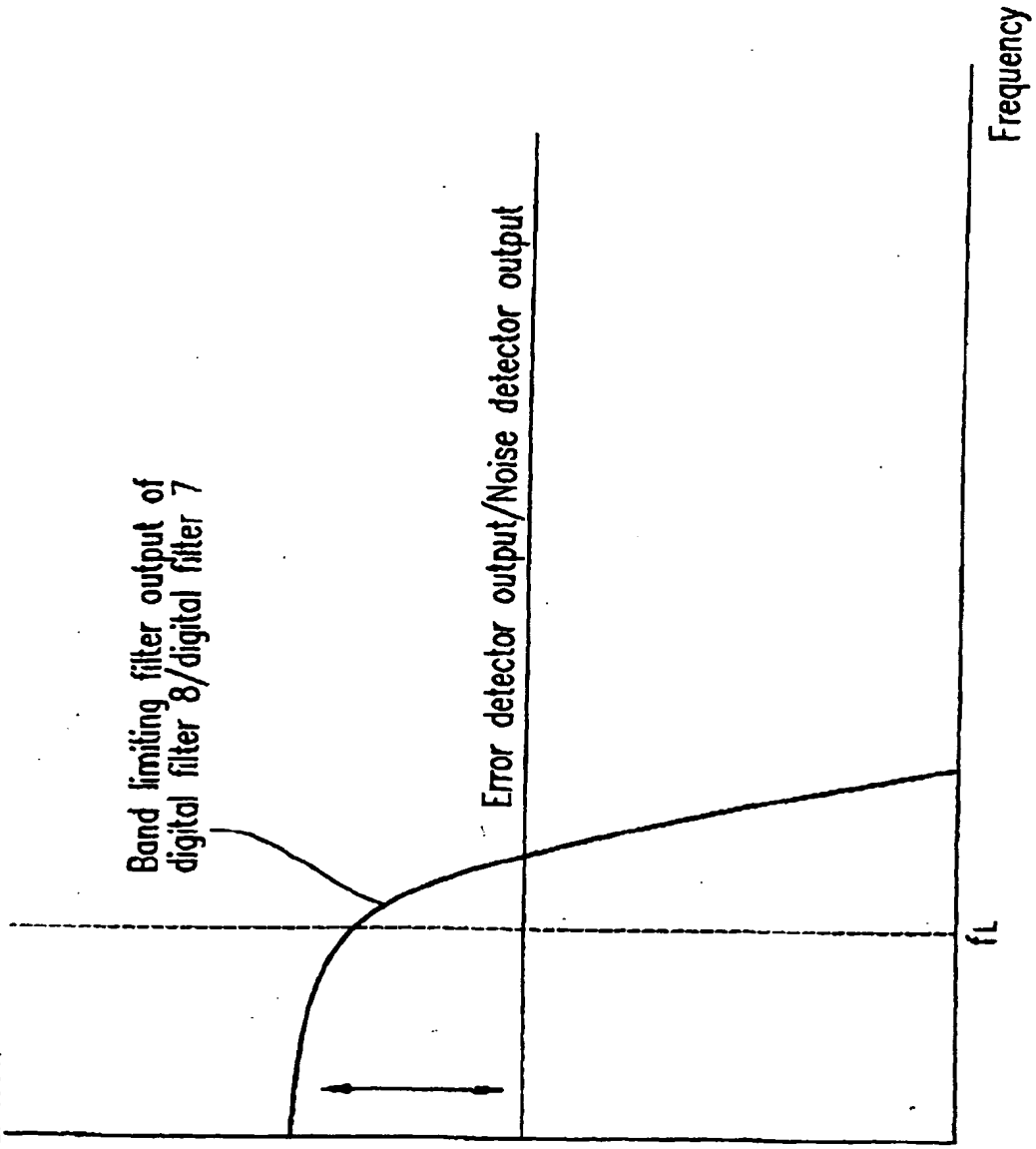

FIG. 17

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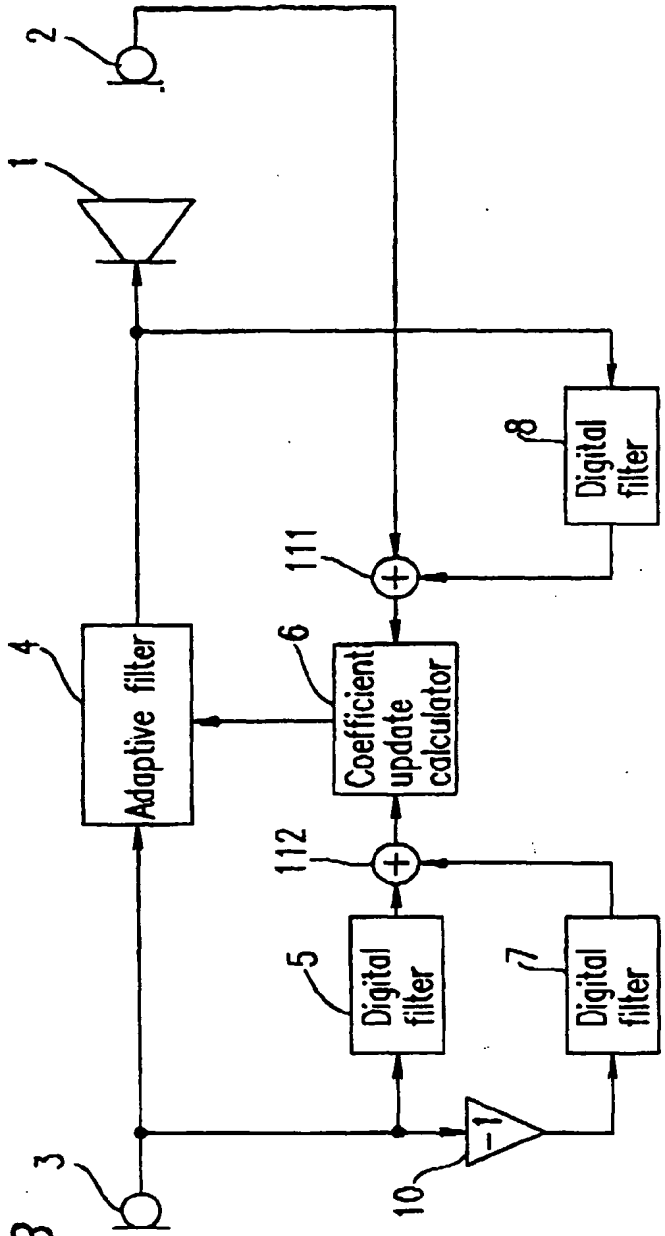
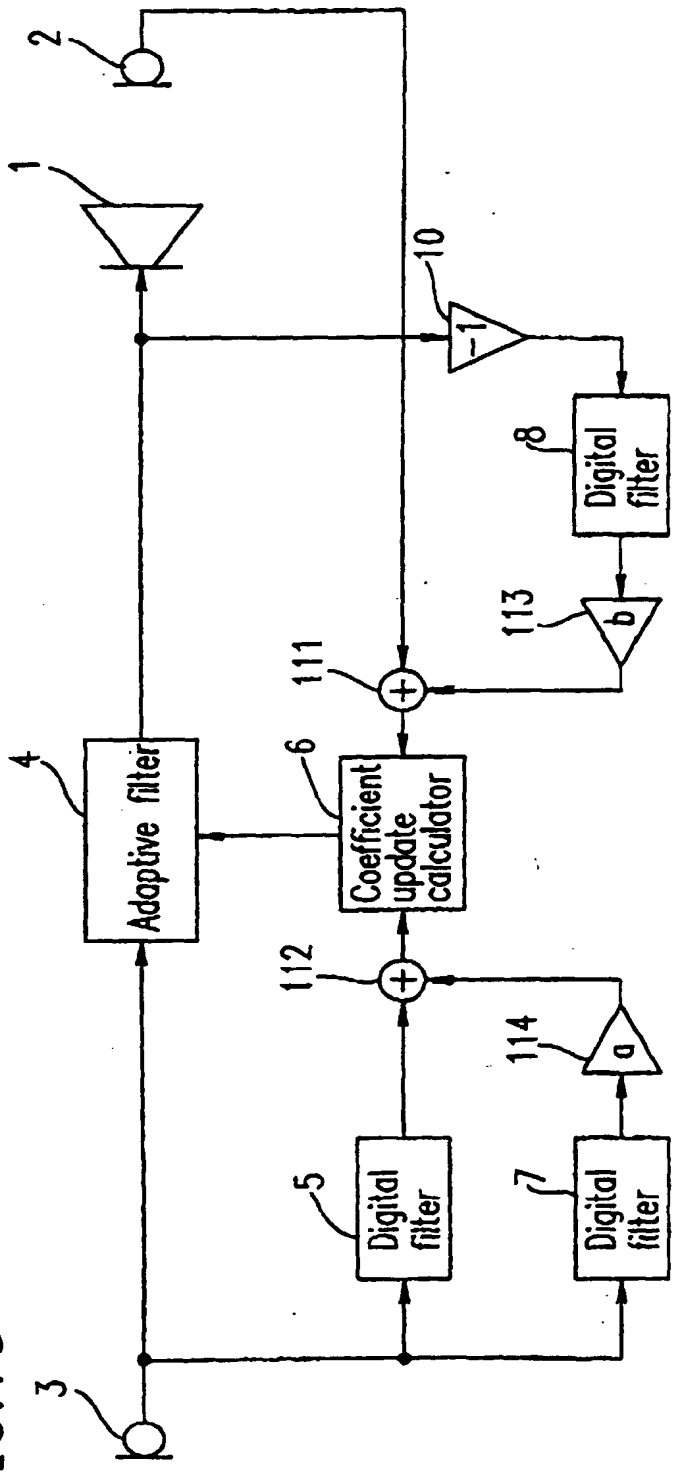

2
1
8
Digital filter
111
4
Adaptive filter
6
Coefficient update calculator
112
5
Digital filter
7
Digital filter
-1
3
10

FIG. 18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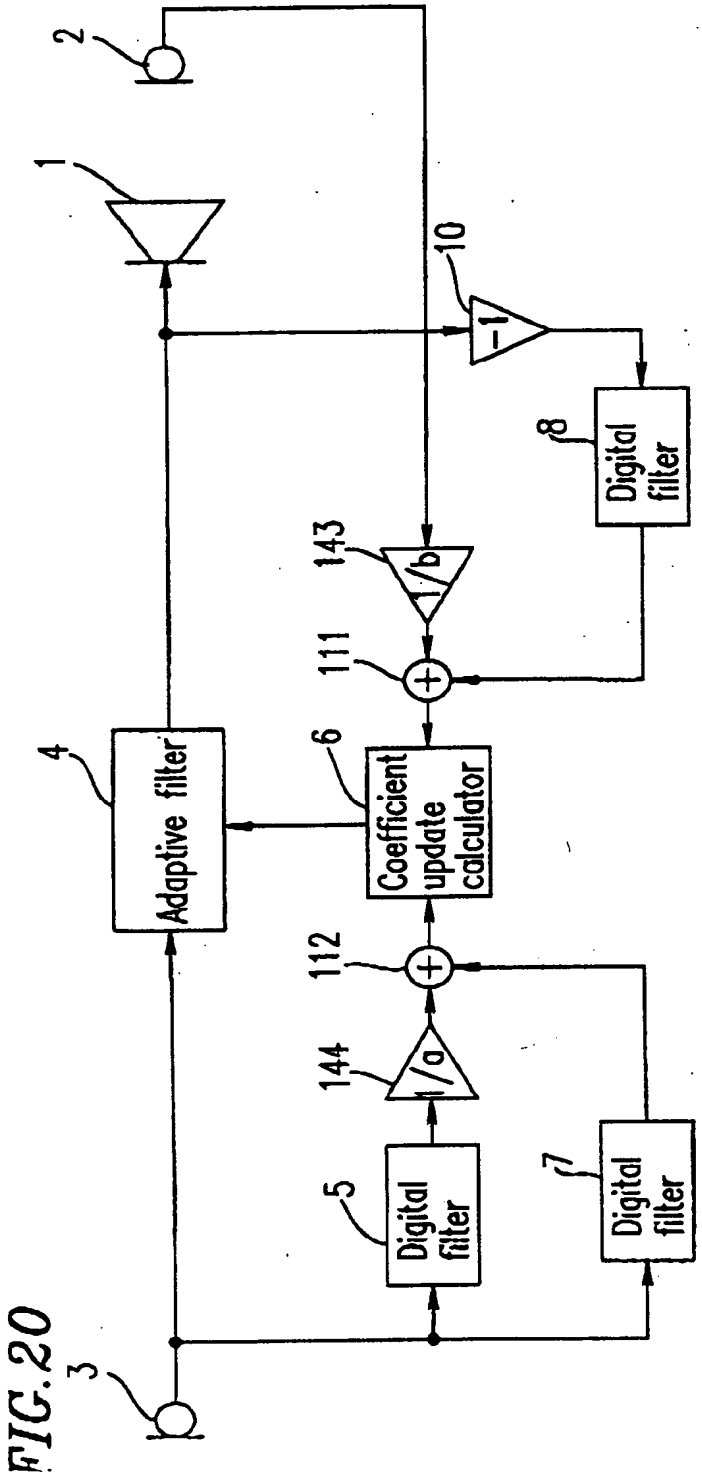
1
10
-1
8
Digital filter
113
b
111
4
Adaptive filter
6
Coefficient update calculator
112
114
a
5
Digital filter
7
Digital filter
3

FIG. 19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-1
8
Digital filter
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1/b
111
4
Adaptive filter
6
Coefficient update calculator
112
144
1/a
5
Digital filter
7
Digital filter
3

FIG.20

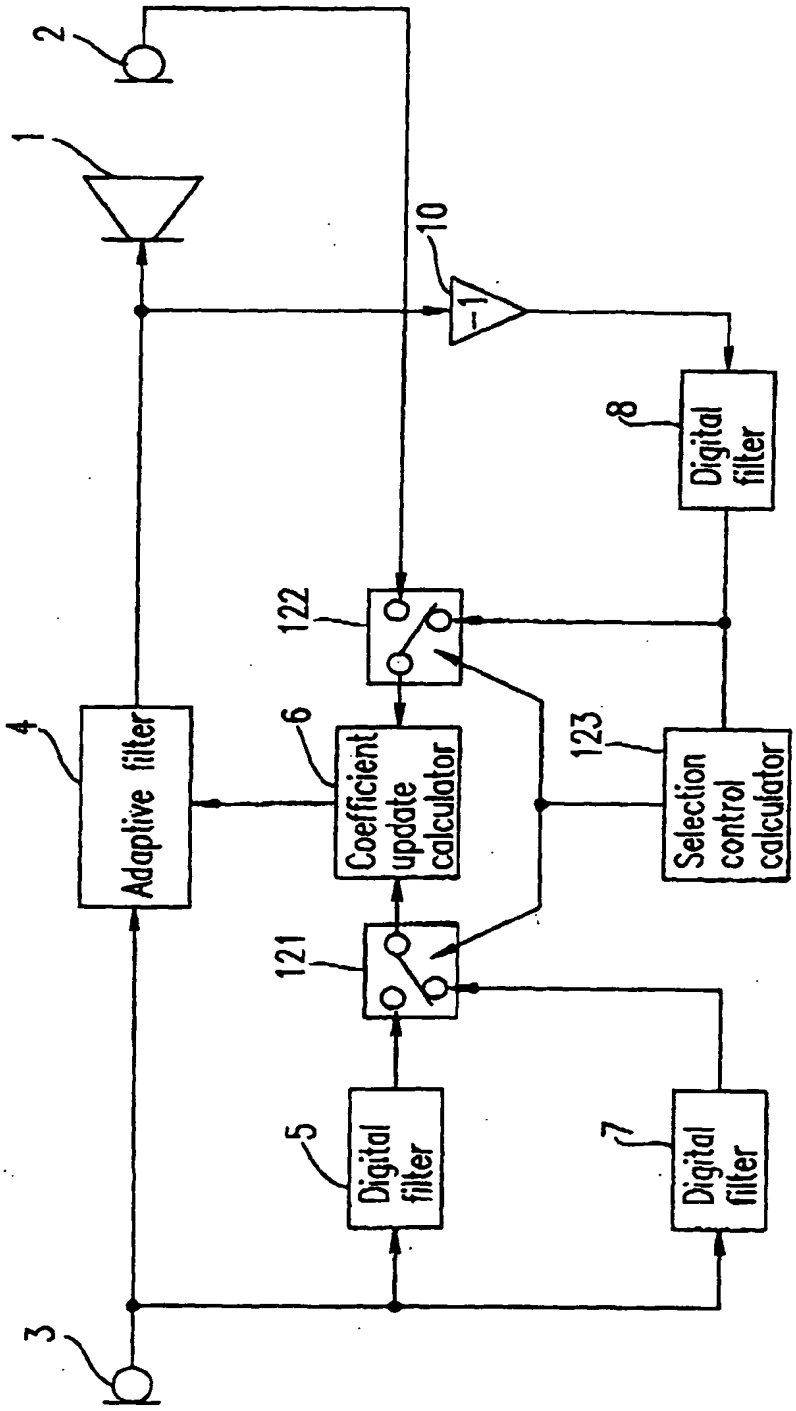

FIG.21

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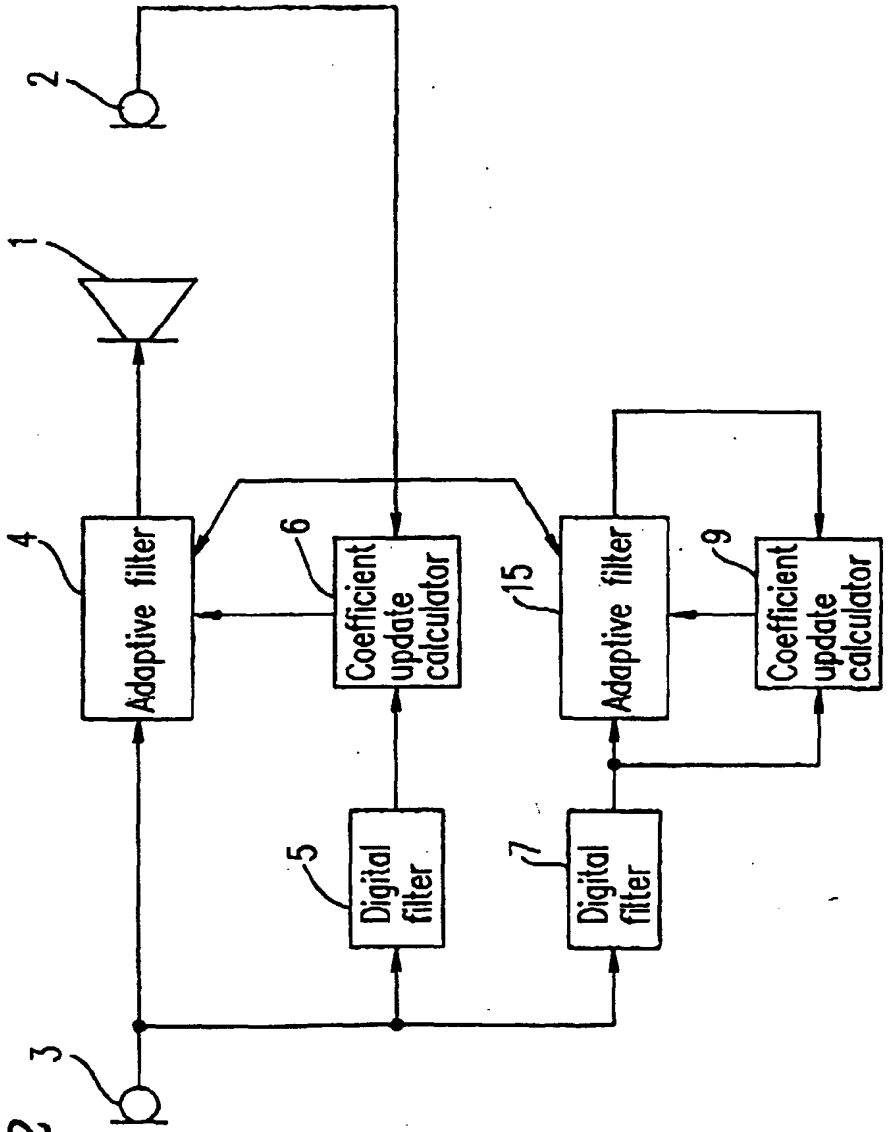
2
1
4
Adaptive filter
6
Coefficient update calculator
15
Adaptive filter
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Coefficient update calculator
5
Digital filter
7
Digital filter
3

FIG.22

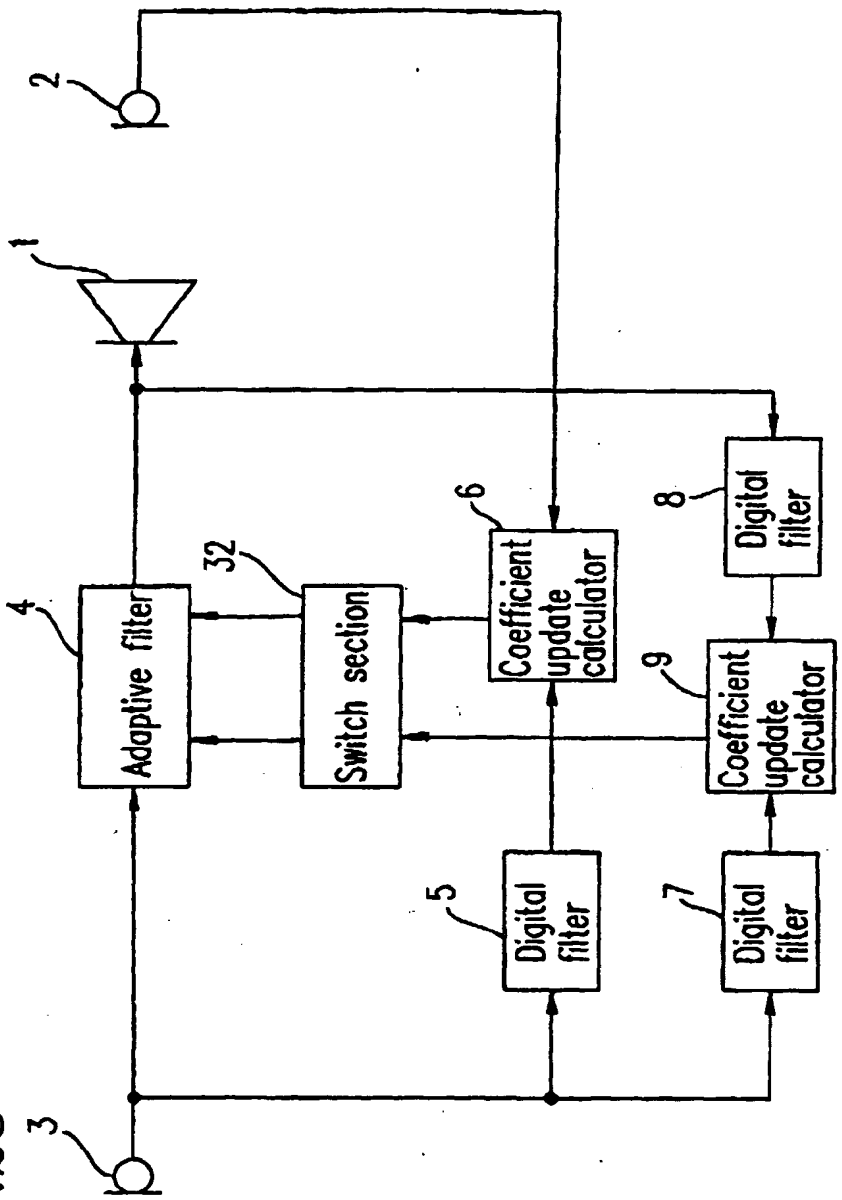

FIG.23

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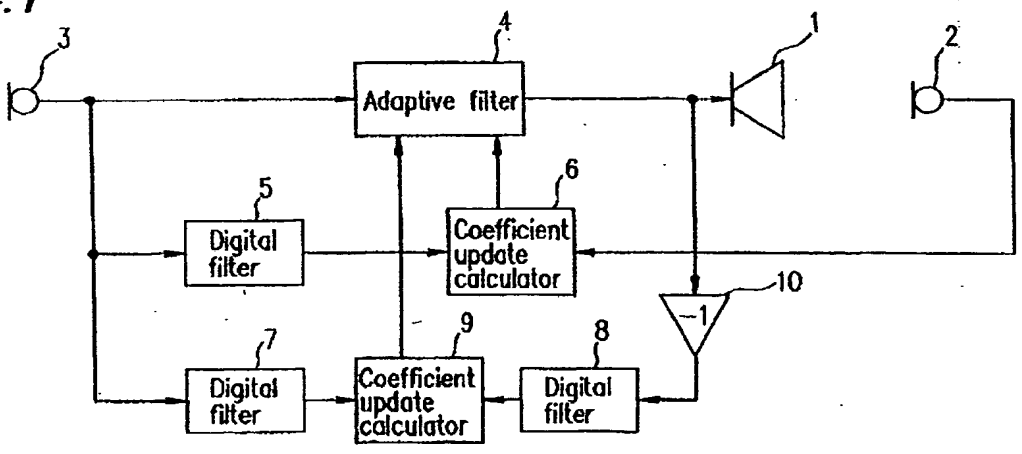
(54) Noise control system

(57) A noise control system includes: a control sound generator (1) for generating a control sound; an error detector (2) for detecting an error signal between the control sound and noise; a noise detector (3) for detecting a noise source signal; an adaptive filter (4) for outputting a control signal; and a coefficient updator for updating a coefficient of the adaptive filter (4). The coefficient updator includes at least a first digital filter (5), a first coefficient update calculator (6), a second digital filter (7), a phase inverter (10), a third digital filter (8), and a second coefficient update calculator (9). Alternatively, the coefficient updator includes at least a first digital filter, a second digital filter, a third digital filter, a coefficient update calculator, a phase inverter, a first adder, and a second adder. In either case, the coefficient updator has a function of suppressing an increase in a coefficient gain of the adaptive filter in a predetermined frequency band.

FIG. 1



EP 0 973 151 A3

BNSDOCID: <EP 0973151A3 I >

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 11 3651

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
D,X	PATENT ABSTRACTS OF JAPAN vol. 1996, no. 02, 29 February 1996 (1996-02-29) & JP 07 271383 A (SANYO ELECTRIC CO LTD), 20 October 1995 (1995-10-20) * abstract *	1-3,7,8	G10K11/178
X	EP 0 616 314 A (TOKYO SHIBAURA ELECTRIC CO) 21 September 1994 (1994-09-21) * page 11, column 20, line 48 - page 12, column 22, line 36; figure 5 *	9	
D,A	US 5 278 780 A (EGUCHI MASAKI) 11 January 1994 (1994-01-11) * column 4, line 65 - line 68; claim 1; figure 1 *	1	
A	EP 0 578 212 A (SHARP KK) 12 January 1994 (1994-01-12) * claim 1; figure 1 *	1	
A	EP 0 773 531 A (DIGISONIX INC ;LORD CORP (US)) 14 May 1997 (1997-05-14) * page 3, line 31 - page 4, line 26; claim 1 *	6	TECHNICAL FIELDS SEARCHED (Int.Cl.7) G10K
A	EP 0 581 565 A (NELSON IND INC) 2 February 1994 (1994-02-02) * claim 1 *	6	
A	EP 0 759 606 A (DIGISONIX INC) 26 February 1997 (1997-02-26) * page 4, column 6, line 44 - line 57 *	6	
A	US 5 535 283 A (SARUTA SUSUMU ET AL) 9 July 1996 (1996-07-09) * column 3, line 36 - column 4, line 3 * * column 8, line 31 - line 41; figure 1 *	9	

-/--

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	5 November 2002	Lorne, B

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

BNSDOCID <EP 0973151A3 >

European Patent Office

Application Number
EP 99 11 3651

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

BNSDOCID: <EP 0973151A3 I >

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 11 3651

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	EP 0 525 456 A (SHARP KK) 3 February 1993 (1993-02-03) * claim 1; figures 1,10 *	9	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	5 November 2002	Lorne, B

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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European Patent Office

LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 99 11 3651

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claims: 1-5,7,8

   A noise control system comprising several coefficient update calculators each associated with a selector for thinning out their outputs. A selection control calculator allows the control of these first and second selection controllers.

2. Claim : 6

   A noise control system comprising several coefficient update calculators, a signal level converter with a characteristic obtained by normalizing an input-distortion characteristic of the control sound generator

3. Claims: 9-20

   A noise control system comprising a coefficient update calculator and two adders.

BNSDOCID: <EP 0973151A3 >

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 99 11 3651

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

05-11-2002

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0525456 A		US 5278780 A	11-01-1994

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82